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CWEA-4 SONIC ANALYZER WITH UH-1 HELICOPTER CAPABILITY

By

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May 1968

U. S. ARMY AVIATION MATERIEL LABORATORIES FORT EUSTIS, VIRGINIA

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CURTISS-WRIGHT CORPORATION
CURTISS DIVISION
CALDWELL, NEW JERSEY

U S ARMY MATERIEL COMMAND

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The effort reported herein represents a part of an overall program to derive techniques which may be used in the development of diagnostic and inspection equipment for the Army aircraft maintenance.

This report presents the results of the investigation of the use of acoustical energy measurement and analysis to determine the mechanical condition of the propulsion system of UH-1 model helicopters. The results of the program indicate that a sonic analyzer can be developed into a useful tool in the maintenance of Army aircraft.

The acoustical reject limits assigned to some of the components during the reported investigation appear to be too low for practical use. Therefore, an in-house program has been initiated to redefine these limits.

A program, similar to the one reported herein, is in progress for the CH-47 model helicopter.

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CWEA-4 SONIC ANALYZER
WITH
UH-1 HELICOPTER CAPABILITY

Final Report

C-3030

by

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Prepared by

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FORT EUSTIS, VIRGINIA

SUMMARY

The purpose of the work encompassed in this report was (1) to fabricate a CWEA-4 Diagnostic Sonic Analyzer and (2) to design and fabricate a UH-1 helicopter plug-in module with both T53 engine and UH-1 helicopter power train components capability.

The methods employed in achieving this work consisted of (1) analyzing mechanical data to determine the frequencies of the rotating components, (2) performing a microphone survey and locking frequency investigation, (3) analyzing the acoustical data to develop spectral familiarity and to establish initial analyzer programming and system compatibility, and (4) conducting a field application program utilizing the CWEA-4 Sonic Analyzer to correlate analyzer indications with the mechanical condition of the rotating components and to establish analyzer limits.

As a result of the work accomplished under this program, a Curtiss model CWEA-4 Sonic Analyzer, developed under Naval Air Systems Command Contract NOw 66-0704f, was fabricated and delivered to the Army. The UH-1 acoustic plug-in module, delivered with the analyzer, was designed and fabricated under this program to incorporate the T53 engine (models T53-L-1A, T53-L-9, T53-L-9A and T53-L-11) and UH-1 helicopter power train components (transmission and tail rotor gear boxes) capability. The component limits were established during the three-month field application program conducted at the U. S. Army Aviation Center, Fort Rucker, Alabama.

A training program was conducted both at the U. S. Army Aviation Center, Fort Rucker, Alabama, and at the U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, to instruct personnel in the operation and maintenance of the CWEA-4 Sonic Analyzer as well as in the diagnostic sonic analysis concept.

The utilization of the CWEA-4 Sonic Analyzer by ground maintenance personnel at a military installation, such as Fort Rucker, Alabama, will reduce the aircraft downtime by eliminating unnecessary troubleshooting as now being practiced under conventional inspection methods. As the confidence level in the CWEA-4 analyzer is increased, the time between periodic inspections may also be increased.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure		Page

Figure | | Page

LIST OF TABLES

Table		Page

Table		Page

LIST OF SYMBOLS AND ABBREVIATIONS

ADGB	Accessory drive gear box
AC	Alternating current
Brg	Bearing
C_1	1st-stage compressor rotor
CAL	Calibrate
cps	Cycles per second
CWEA	Curtiss-Wright Engine Analyzer
d_1	Bearing inner race diameter, inches
d_2	Bearing outer race diameter, inches
db	Decibel
d_B	Bearing rolling element diameter, inches
Diff	Differential
Eng	Engine
f_1	Bearing frequency caused by irregularity on inner raceway, cps
f_2	Bearing frequency caused by irregularity on outer raceway, cps
f_B	Bearing frequency caused by spin of rolling element, cps
f_B'	Bearing frequency caused by rough spot on rolling element, cps
$3f_B'$	Third harmonic of f_B' (3 times f_B'), cps
f_L	Locking frequency, cps

f_R	Fundamental rotational frequency of engine, gear shaft or bearing shaft, cps
f_T	Bearing frequency due to rotation of train of rolling elements, cps or tracking frequency, cps
FS	Full scale
Gen	Generator
Gov	Governor
Hrs	Hours
Hyd	Hydraulic
I.D.	Inside diameter, inches
KC	Kilocycles
Locking Signal	The frequency utilized for tracking engine rpm variation (within ± 1%) which must be present on all engines 100% of the time and does not have any other discrete signals within ± 400 cps. (Any variation in engine rpm above or below the ± 1% range will alter this limit accordingly.)
m	Number of bearing rolling elements
Max	Maximum
Mic	Microphone
MRC	Marlin-Rockwell Company
MR	Material review
MV	Millivolt
N	Revolutions per minute
N_1	Gas producer rotor speed, rpm
N_2	Power turbine rotor speed, rpm

ND	New Departure
NH	Norma Hoffman Bearing Company
No. Nos.	Number
O.D.	Outside diameter, inches
OUPT	Output
OVSP	Overspeed
P/N	Part number
Ref	Reference
RPM, rpm	Revolutions per minute
RPS	Revolutions per second
S/N	Serial number
SKF	SKF Industries, Inc.
Tach	Tachometer
TBO	Time between overhauls
TT	Total time
TSO	Time since overhaul
Xmsn	Transmission

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INTRODUCTION

The purpose of the work included in this report was to deliver a CWEA-4 Sonic Analyzer with the capability of analyzing the UH-1 series helicopter dynamic components system. The specific UH-1 helicopter models, including engine models, for which this analyzer was designed are as follows:

UH-1 Helicopter Model	T53 Engine Model
UH-1A	T53-L-1A
UH-1B	T53-L-9, -9A, -11
UH-1C	T53-L-9, -9A, -11
UH-1D	T53-L-9, -9A, -11

To accomplish this program, it was necessary (1) to perform a mechanical analysis of all rotating train components of the above model UH-1 helicopters, for the calculation of the expected acoustic frequencies, (2) to compile an acoustic handbook listing these acoustic frequencies including the frequencies of the engine components determined under contract NOw 66-0704f, (3) to conduct an acoustic survey of a number of UH-1 series helicopters to determine optimum microphone location and to establish the best locking frequency, (4) to perform a laboratory analysis of all acoustic recordings for identification of engine components, (5) to design and fabricate an acoustic plug-in module with UH-1 complete dynamic component system capability to be utilized with the CWEA-4 analyzer, (6) to fabricate a CWEA-4 Sonic Analyzer designed under contract NOw 66-0704f, and (7) to perform a field evaluation of the CWEA-4 analyzer.

The objectives of this report are (1) to present the results of the work performed in the application of the CWEA-4 Sonic Engine Analyzer to the UH-1 complete dynamic component system, (2) to include the results of the design and development of the UH-1 acoustic plug-in module, and (3) to describe the CWEA-4 analyzer, including the design concepts.

The Curtiss-Wright Corporation has been engaged in the research and development of a new technique for diagnosing engine malfunctions since early 1960. A new concept for analyzing jet engines and power transmission systems, designated the Diagnostic Sonic Analysis Technique, has been developed together with the design and fabrication of four analyzer models under previous Government contracts (USN BuWeps Contracts NOw 60-0746c, NOw 62-0721c, NOw 65-0094f and NOw 66-0704f). In addition to these Navy contracts, company-funded research and development programs between Government contracts led

to the development of the frequency ratio generator, intermediate frequency amplifier, and plug-in module circuitry; and under the U. S. Army, USAAVLABS contract DA44-177-AMC-249(T), a gear study was made of power transmission systems.

Current projects include the following Government contracts as well as analyzer evaluations for both Eastern and National Airlines:

U. S. Navy Contracts

NOw 66-0631d	J65 Engine Compressor Surge Control Program
N62269-67-C-0159	J52 Engine Analyzer
N62269-68-C-0040	CH-46 Helicopter Dynamic System

U. S. Army Contracts

DAAJO2-67-C-0006	CH-47 Helicopter Dynamic System

The effective date of the contract discussed in this report was 28 June 1966.

DISCUSSION

DATA ACQUISITION AND ANALYSIS

Mechanical Data and Analysis

The mechanical data for the various rotating components of the model UH-1A, UH-1B, UH-1C and UH-1D helicopters were obtained from the Department of the Army Technical Manual No. 55-1520-210-35P-1 dated February 1966, from the blueprint files at the U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, and from various bearing manufacturers. The type of data required for a mathematical analysis of the rotating components included the following:

1. Power transmission operating speeds.

2. Gear train assemblies, drives and number of gear teeth for each gear concerned.

3. Accessories, their location and internal assemblies.

4. All bearings, their location and dimensions of races and rolling elements.

5. Aircraft engine installation and transmission and tail rotor gear box locations.

Utilizing the mechanical data as obtained above, the predicted frequencies of the various rotating power train components were calculated as shown in the appendix. These predicted frequencies together with those computed for the model T53-L-1A, T53-L-9, T53-L-9A, and T53-L-11 engines under contract NOw 66-0704f are tabulated in Tables I through XXXVIII.

The gear train schematics for the T53 engine and the power train components of the UH-1 helicopter are shown in Figures 1 through 9. The identification code used in Figures 1 through 9 is as follows:

1. The number written in parentheses is used for the identification and location of the individual components.

2. The number printed on the gears indicates the number of gear teeth.

3. The number underlined indicates the component shaft speed, rps.

The model T53-L-1A engine gear train schematics for both the gas producer (N_1) and power turbine (N_2) sections are shown in Figures 1 and 2, respectively. The model T53-L-9, T53-L-9A and T53-L-11 engine gear train schematics for both the gas producer (N_1) and power turbine (N_2) sections are shown in Figures 3 and 4, respectively. The gear train schematics of the main rotor transmission for models UH-1A, UH-1B, UH-1C and UH-1D helicopters are shown in Figures 5, 6, 7 and 8, respectively; and a gear train schematic of the tail rotor gear boxes for models UH-1A, UH-1B, UH-1C and UH-1D helicopters is shown in Figure 9.

Acoustic Data and Analysis

Microphone Location Survey

The initial microphone survey of models UH-1A, UH-1B, UH-1C and UH-1D helicopters was conducted at the U. S. Army Aviation Center, Fort Rucker, Alabama, during the period of 13 September to 21 September 1966. The purpose of this survey was (1) to establish the optimum microphone locations utilized for detecting signals from the rotating components of the engine, transmission, and tail rotor power train, and (2) to determine the components to be utilized for rpm tracking.

Sixteen helicopters were surveyed utilizing a magnetic tape recorder and four condenser type microphones to record the data. A summary of the helicopters surveyed showing the model T53 engines and helicopter power train components (transmission and tail rotor gear boxes) analyzed is presented in Tables XXXIX and XL, respectively. During this survey, the microphones were located at various positions adjacent to the engine transmission and tail rotor components to obtain the optimum locations designated below:

Microphone No.	Microphone Location
1	UH-1 transmission - right side (aimed at vertical centerline of transmission center section).
2	Engine forward section - right side (aimed at the accessory drive gear box).
3	Engine aft section - right side (aimed at No. 3 and No. 4 bearings).
4	Engine forward section - left side (aimed at overspeed governor and tachometer gear box).

Microphone No. 1 extended 10 inches inside the aircraft cowling (through access panel). Microphones Nos. 2, 3 and 4 extended two to four inches inside the aircraft cowling (through access panels) and were aimed radially toward the engine components listed above.

A limited number of recordings were obtained with Microphone No. 3 positioned approximately 2 inches away from the louvers on the tail boom (right side) in the vicinity of the 42-degree gear box. Detection of both the 42-degree and 90-degree gear box components was accomplished utilizing this single microphone.

The engine and transmission operating speeds for ground operation of the various UH-1 helicopter models at flight idle conditions were established as designated below:

Helicopter Component	Tachometer Setting
Engine N_1 Drive	60%
Transmission Input Shaft Drive or Engine N_2 Output Shaft Drive	4500 rpm

These speeds were maintained as close as possible during the initial survey.

The characteristics of the various component signals were analyzed using a standard wave form analyzer with associated electronic equipment. In addition to determining the optimum microphone locations, it was also initially established that (1) the engine third-stage compressor rotor provided a satisfactory signal for use as the engine N_1 locking frequency and (2) the transmission input drive bevel gear train provided a satisfactory signal for the engine N_2 and transmission locking frequency. However, a more complete analysis of the recorded data indicated that the engine second-stage compressor rotor provided a more stable N_1 locking signal. It was also determined that the same microphone could be utilized for both the N_1 and N_2 locking signals.

RPM Tracking Tests

As a result of the experience gained in setting the N_1 and N_2 speeds on the UH-1 series helicopters at Fort Rucker, Alabama, during the initial acoustic survey, the nominal speed settings for the analyzer plug-in module were selected as follows:

Engine Compressor Shaft Speed (N_1) = 60%

Transmission Input Drive Shaft Speed* = 4500 rpm

Since it was anticipated that all models of the UH-1 helicopters (UH-1A, UH-1B, UH-1C and UH-1D) surveyed could be set at the above speed settings for the sonic analyzer checks, a single plug-in module design was proposed. The locking frequencies utilized in this design, based on the speed settings selected above, are as follows:

RPM Dependent Components	Locking Component	Locking Frequency (cps)
N_1	Engine Second-Stage Compressor Rotor	7042
N_2	Transmission Input Drive Bevel Gear	2175

The use of a single plug-in module requires that some helicopter models be operated at N_1 and N_2 speed settings that may differ from the nominal rigging speeds. However, the advantage of having a single module for all model helicopters justifies the operation of these various models at the particular speed condition selected above.

The experience in setting the above N_1 and N_2 speeds, using the aircraft tachometer indicators for reference, indicated that the N_1 and N_2 speeds could be set within a range of 58-62% and 4400-4600 rpm, respectively. The speed drift during the time required to obtain the recordings was estimated to be less than 1% for the engine N_1 speed and less than 100 rpm for the transmission (engine N_2)speed. The equivalent speeds and locking frequencies that apply to the design of the plug-in module are summarized below based on the nominal speeds of 60% for the engine N_1 and 4500 rpm for the transmission.

Engine N_1 Tachometer - %	Deviation from Nominal - %	Locking Signal Frequency - cps
57	- 3	6688
58	- 2	6806
59	- 1	6924
60	0	7042
61	+ 1	7160
62	+ 2	7278
63	+ 3	7396

* Equivalent to engine power output shaft speed N_2.

Transmission Tachometer rpm	Deviation from Nominal - %	Locking Signal Frequency - cps
4300	- 3	2079
4368	- 2	2111
4400	- 1.5	2127
4434	- 1	2143
4500	0	2175
4566	+ 1	2207
4600	+ 1.5	2223
4632	+ 2	2239
4700	+ 3	2271

A summary of the speeds and equivalent locking frequencies for the helicopters checked during the initial acoustic data survey at Fort Rucker, Alabama, are summarized as follows:

Serial Number	Model Number	N1 Speed		N2 Speed	
		%	cps	rpm	cps
59-1639	UH-1A	62.5	7330	4530	2190
59-1709	UH-1A	64	7495	4575	2210
60-3537	UH-1A	61	7160	4500	2175
58-2084	UH-1A	62	7270	4520	2185
62-1925	UH-1B	60	7040	4350	2105
65-0741	UH-1B	60.3	7080	4600	2220
62-12533	UH-1B	60.3	7080	4500	2175
61-0719	UH-1B	58	6800	4150	2005
62-1928	UH-1B	60.3	7080	4500	2175
62-1926	UH-1B	60.5	7120	4650	2250
65-9534	UH-1C	59.5	6990	4300	2070
61-14120	UH-1C	64.5	7550	4450	2150
65-9491	UH-1C	62.3	7300	4450	2150
65-9502	UH-1C	63.2	7425	4400	2120
65-9750	UH-1D	63	7400	4500	2175
65-9899	UH-1D	60.5	7120	4160	2010

Spectral Familiarization

A spectral analysis was made of the above recordings to confirm the presence of the two signals proposed for the N_1 and N_2 locking frequencies and also to determine the identity and characteristics of the various component signals. The results of this analysis confirmed that the engine second-stage compressor rotor signal and the transmission input drive bevel gear signal appeared at a satisfactory level using microphone No. 1 (right side of the transmission). The major rotating components of the engine, transmission, and tail rotor power train were also identified.

A spectrogram obtained from helicopter serial number 62-1925 of the engine compressor signals using microphone No. 1 is shown by Figure 10. This spectrogram shows the relatively strong signal exhibited by the second-stage compressor rotor as compared with the background noise level and is typical of the spectrograms obtained from other helicopters. This spectrogram also confirms that the second-stage compressor rotor is a better choice for the N_1 locking signal than the third-stage compressor rotor. Figure 11, which is a spectrogram obtained from helicopter serial number 62-1925, shows a typical engine N_2 output gear signal. Another spectrogram obtained from this helicopter of the transmission gear signals using microphone number 1 is shown by Figure 12. This spectrogram shows the relatively strong signal from the input drive bevel gear as compared with the background noise level and is typical of the spectrograms obtained from other helicopters. This spectrogram also shows the signal from other gears in the engine and transmission.

A spectrogram obtained from helicopter serial number 59-1709 of the tail rotor drive gear boxes using the microphone on the tail boom is shown by Figure 13. This spectrogram shows the strong signals obtained from the bevel gears in the 42-degree and 90-degree gear boxes and is typical of the spectrograms obtained from other helicopters.

UH-1 Helicopter Component Rejection Limits for the CWEA-4 Sonic Analyzer

The analyzer component gain settings, which determine the component condition level as read on the condition meter, are established in two phases of the overall program. The initial limits are derived from the analyses of recorded data which are obtained during the early phases or component familiarization portion of the program. These values may also be referred to as the preliminary field testing limits. In those cases where the program provides for field evaluation or testing of the analyzer, these initial limits are further refined and/or revised to establish component condition levels

under actual field conditions. The preliminary work and results of tests accomplished under previous phases of programs have shown that the engine is treated as a collection of bearings, gear trains, accessories, compressors and turbine stages. Likewise, a transmission is treated as a collection of bearings and gear trains. The ability to treat a gear train as such instead of an integral component of a specific engine or transmission allows a large amount of carry-over of information from one system to another. Consequently, the criteria used for establishing limits for an earlier analyzer model may be applied to subsequent analyzer programs.

The preliminary engine/transmission component condition limits were established utilizing the UH-1 helicopter data recorded at Fort Rucker, Alabama, in September 1966. The analysis of these data consisted of establishing a gain setting required to produce a half-scale deflection of the condition level meter for the rotating components associated with the N_1 and N_2 sections of the engine as well as with the transmission and tail rotor components. These gain values are subsequently revised to correspond to low meter read-out for low or normal component signals and high meter read-out for those same component signals found to have greater amplitudes.

During the field testing, or real time analysis, the analyzer limits are tested and refined if necessary to compensate for the mode of operation. In the event that confirmation of the mechanical condition of a part is accomplished, the analyzer limits are confirmed or adjusted accordingly. A discussion of these analyzer limit modifications and mechanical confirmations is presented in the section under "Field Application Program".

Microphone Normalization

All microphones must be normalized to obtain a relative comparison of the amplitudes of all engine/transmission component signals. This is accomplished by selecting the lowest background noise level at a frequency in the overall system noise spectrum that does not contain any discrete signals. A thorough analysis of all the data recorded in the aircraft resulted in establishing this normalization frequency as 8175 cps. All microphones can be normalized for half-scale deflection of the analyzer condition level meter at this frequency using the "N_1" locking signal.

PLUG-IN MODULE DESIGN

UH-1 Helicopter Phase Locked Loop Specifications

The operation of the phase locked loop is as described in the Operation and Maintenance Manual for the CWEA-3, -4 Analyzer. A block diagram for the Phase Locked Filter is presented in Figure 14. The tracking capability of the loop is based on capturing the signal of a component on the aircraft and then using this signal to monitor the variation of the engine speed (within $\pm$ 3% of idle) while remaining synchronous with the aircraft. The signals used to lock on to the UH-1 helicopter are:

N_1 - Second-Stage Compressor Rotor Frequency at Idle, 7042 cps

N_2 - Transmission Input Bevel Gear Frequency at Idle, 2175 cps

Since the optimum operating range - based on the aircraft spectrum and on circuit performance - for the analyzer has been established as between 5000 and 8000 cps, the N_2 locking frequency for the UH-1 helicopter is multiplied by three. The tracking frequencies for the UH-1 helicopter are thus:

N_1 - 7042 cps

N_2 - 6525 cps

The tracking frequencies are then used as a reference to monitor all the rotating components on the aircraft.

Based on the above specifications, an acoustic plug-in module was designed and fabricated for the CWEA-4 Sonic Analyzer to provide UH-1 helicopter capability.

FABRICATION OF CWEA-4 SONIC ANALYZER

Design of CWEA-4 Automation Equipment

Theory of Operation of Automation Data Loop

The sonic engine analyzer is required to monitor two distinct types of signals because of the nature of malfunctions in jet engine and power transmission components. In the first type, such as that produced by bearings, the

analyzer is required to monitor only the amplitude of the signal above the noise background. The second type is produced by components that generate sidebands and/or harmonics as an indication of deterioration. In this case, the analyzer is required to monitor the amplitude of the sidebands and/or the harmonics of the normal component frequency with respect to the amplitude of the so-called carrier frequency. Compressor unbalance is a classic example of this type of spectrum since unbalance is characterized by high amplitude sidebands.

A brief description of how the automation loop of the sonic engine analyzer will monitor each type of signal is as follows (refer to the block diagram in Figure 15):

1. Amplitude - Switches K3 and K5 are closed by energizing magnetic latching relays allowing the signal for a particular component to appear at the input to a voltage comparator, VC1. The amplitude of this signal is then compared to a fixed voltage reference. If the signal is above the reference, the comparator is turned on, providing a step input to the control circuit driver. The driver energizes a magnetic latching relay which will (1) open the clock input to the paper tape driver and thus stop the process and (2) light the indicator lamp, indicating that the component exhibits an amplitude above a predetermined limit.

2. Sideband/Harmonic - The analyzer is programmed to monitor the ambient noise in the vicinity of a component, and switches K1 are closed by energizing a magnetic latching relay. Capacitor C1 is then charged up to a dc level corresponding to this ambient noise. Switches K1 are now opened, allowing the voltage on C1 to be stored in AR2. Switch K3 is now closed, allowing the signal for a component to enter the loop. The component signal thus appears at one input to AR3 and the ambient noise at the other. The output of AR3 is thus the difference between the two dc levels; i.e., it is the actual amplitude of the signal above the noise. If this signal corresponds to the "carrier", switch K2 is closed, thereby charging up capacitor C2 to a dc level corresponding to the true amplitude of the carrier. K2 is then opened, storing this information in AR5. This dc level now forms the reference input for voltage comparator VC2. If the signal at the output of AR3 corresponds to a sideband or a harmonic of a particular component, K4 is closed, allowing the output of AR6 to provide the signal input to VC2. Switches K6 and K7 are provided to vary the

gain of AR6 in order to skew the signal to a level appropriate for monitoring the component in question. If the amplitude of the sideband or harmonic is greater than a predetermined percent of the "carrier" amplitude, the voltage comparator will turn on, thus providing a step to the control circuit driver which will light the indicator and open the loop to stop the process.

3. Operation Details - Amplifiers AR1 and AR 4 are used as buffers to isolate inputs from outputs, and switches K8 are provided to clear the information stored in AR2 and AR5 when necessary. A manual reset is available in the control circuit driver to unlatch the control relay after a faulty component is monitored. A time delay is inserted at the input to the automation loop in order to allow the analyzer to reach a steady-state level. This will prevent the automation loop from monitoring any transients that may occur and thus prevent false interpretation of the data.

   All logic necessary for setting the analyzer to monitor a particular component and also all necessary switching required in the automation loop will be performed by programming a paper tape reader. All the operator will be required to do is manually adjust a potentiometer to normalize the overall noise level (the logic necessary for this operation will also be programmed into the paper tape reader) and then close the automation switch to start the process.

   The automatic operation of the analyzer will be superior to the manual mode of operation in that it will:

   a. Eliminate the operator's bias on how to monitor the data.

   b. Virtually eliminate the human error in adjusting the settings necessary for monitoring each component.

   c. Provide a more efficient method of monitoring sidebands and harmonics of signals than is possible in the manual mode.

Typical Paper Tape Program for CWEA-4

Typical sample copies of a paper tape program which were programmed for the CWEA-4 analyzer with the UH-1 plug-in module are shown in Figures 16 and 17.

Figure 16 shows the beginning of a paper tape program in that it illustrates the starting command for the tape reader, the clearing of all stored logic and data from the analyzer, the calibration of the module for each spool on the aircraft, the normalization of the incoming data from the microphone(s) being monitored, and the start of the actual component monitoring. Figure 17 illustrates the sequence used to monitor components which exhibit sidebands as an indication of an impending failure. The fundamental is first monitored for an excessive amplitude. Then the ambient noise in the vicinity of the component signal is sampled and stored. The fundamental is again programmed, this time for storage, and then the sidebands are monitored with respect to the fundamental.

CWEA-4 Analyzer Description

A complete description and operation of the CWEA-4 analyzer is given in the Operation and Maintenance Manual for the CWEA-3, -4 Sonic Analyzer delivered with the analyzer. A complete parts list is also included in this manual. A photograph of the CWEA-4 analyzer system (including power supply and microphones) is shown in Figure 18, and a close-up view of the analyzer panel is shown in Figure 19.

In addition to the Operation and Maintenance Manual, an acoustic handbook has been compiled for the UH-1 helicopter. The purpose of this handbook is to provide ready reference to mechanical information and frequency data essential for sonic analysis of the UH-1 helicopter and the T53 turboshaft engine components and accessories. This handbook is divided into three sections: Section I covers the models T53-L-9, T53-L-9A and T53-L-11 engines; Section II covers the model T53-L-1A engine; and Section III covers the UH-1 helicopter main rotor transmission and tail rotor gear boxes for models UH-1A, UH-1B, UH-1C and UH-1D.

This handbook includes the following information:

1. Cutaway views of the various model T53 engines.

2. General arrangement configuration of the various model UH-1 helicopters.

3. Transmission configuration for the UH-1 series helicopters.

4. Gear train schematics for both the gas producer (N_1) section and power turbine (N_2) section of the engines.

5. Gear train schematics of the main rotor transmission and tail rotor gear boxes for the various model UH-1 helicopters.

6. Sample calculations for determining the frequencies of the rotating components.

7. Tabulations of the predicted frequencies of the rotating components.

8. A listing of the phase locking frequencies for both acoustic locking (helicopter installation) and tachometer locking (test cell operation).

9. Tabulations of the octal ratios used in the operation of the CWEA-4 analyzer for both the helicopter installed engines (acoustic locking) and for test cell operated engines (tachometer locking).

10. Microphone locations for engines installed both in the helicopter and in the test cell.

11. Microphone locations for the main rotor transmission and tail rotor gear boxes.

FIELD APPLICATION PROGRAM

Manual Operation - CWEA-3 Sonic Analyzer

The initial phase of the field application program was conducted using the model CWEA-3 Sonic Analyzer. A photograph of this analyzer is presented in Figure 20. This analyzer was placed in operation at the U. S. Army Aviation Center, Fort Rucker, Alabama, during the period from 20 March to 4 May 1967. During this period, 16 UH-1 helicopters were analyzed. The primary purpose of this initial phase of the field evaluation program was (1) to confirm satisfactory operation of the analyzer using the manual control mode, i.e., the component select, component gain, microphone select, and lock select controls being operated manually for each component analyzed; (2) to gain experience in the operation of the analyzer; (3) to investigate any difficulties associated in operating the helicopters at the desired engine speed settings; (4) to determine the maximum variation in the engine speed settings with regard to the rpm capture and track capabilities of the analyzer; and (5) to record the condition level meter readings for each component selected using tentative gain settings.

Prior to placing the CWEA-3 analyzer in the field, a variety of engine, transmission, and tail rotor power train components were arbitrarily selected for analysis, and tentative gain settings for each component were established based on the data obtained from the initial acoustic survey.

The microphone locations used for the various model helicopters analyzed during this phase of the program are summarized below:

Microphone No. 1	Located approximately 10 inches inside the transmission right-hand inspection door and aimed at the center section of the transmission on the vertical centerline for aircraft models UH-1A, UH-1B and UH-1C. On model UH-1D aircraft, located approximately 2 inches from the right-hand side of the transmission cover housing (6 inches above top of cabin) directly opposite the transmission vertical centerline and aimed at the top of the transmission.
Microphone No. 2	Located approximately 10 inches inside the engine left-hand inspection door and aimed at a point halfway between the engine N_1 and N_2 accessory drive gear boxes on a vertical line through the parting line of the two gear box housings.
Microphone No. 3	Located approximately 2 inches from the right-hand side of the 42-degree gear box cover housing and aimed at the center of the gear box.

A three-prong bracket was fabricated for use in mounting microphones Nos. 1 and 2 at the respective transmission and engine inspection doors on all model helicopters except the model UH-1D (see Figure 21). On the model UH-1D, a suction cup was utilized for the microphone No. 1 installation (see Figure 22). A suction cup was also used to mount microphone No. 3 on all model helicopters (see Figure 23).

During this initial phase of the field application program, the analyzer operation was satisfactory and no difficulties were encountered with the helicopter speed settings. Satisfactory capture and track capabilities of the analyzer with respect to engine speeds were demonstrated with N_1 speeds set within 60 ± 2% and N_2

speeds set within 4500 ± 100 rpm. A review of the component condition level readings recorded during this phase of the field program permitted adjustments in the gain settings for certain components.

A summary of the aircraft analyzed during this initial period, along with the historical data on the engines, transmission, and tail rotor drive gear boxes, is given in Tables XLI and XLII. The components of the T53 engine that were selected for analysis, along with the corresponding adjusted gain settings, microphone select, lock select, and condition level limits, are given in Tables XLIII through XLVI. The components of the transmission and tail rotor drive power train that were selected for analysis, along with the corresponding adjusted gain settings, microphone select, lock select, and condition level limits, are given in Tables XLVII through L.

Automation - CWEA-4 Sonic Analyzer

The automation model CWEA-4 Sonic Analyzer was delivered to the U. S. Army Aviation Center, Fort Rucker, Alabama, on 26 June 1967 and was placed in operation at Lowe Field as directed by Army Maintenance Branch personnel at Fort Rucker. A photograph of this analyzer in operation with a model UH-1B helicopter is shown in Figure 24. Eight individual punched paper tapes programmed for specific categories of the engine, transmission, and tail rotor power train components were furnished with the analyzer. The components analyzed utilizing these program tapes, together with the component gain setting, microphone select, lock select, and limit level conditions, are given in Tables XLIII through L.

Preliminary check-out of the analyzer was conducted using recorded data from the previous manual operation, and excellent correlation was obtained among manual, semiautomatic, and automatic modes. A number of helicopters were analyzed to evaluate and confirm the performance of the analyzer. The historical data on the engines, transmissions, and tail rotor gear boxes for the helicopters checked during the period of 28 June to 17 July 1967 using the individual punched paper tapes are given in Tables XLI and XLII. The condition level data on the components of the T53-L-9A and T53-L-11 engines checked during this period are given in Tables LI and LII, and the component item numbers corresponding to the program sheet components are given in Tables XLV and XLVI, respectively. The condition level data on the transmission components are given in Tables LIII, LIV and LV with the component item numbers corresponding to the program sheet components given in Tables XLVII, XLVIII and XLIX, respectively. The condition level data on components of the tail rotor drive train are given in Table LVI, with the component item numbers corresponding to the program sheet components given in Table L.

The experience gained during this check-out period in the operation of the automated CWEA-4 analyzer indicated the desirability to reduce the number of punched paper tapes supplied with the analyzer. Therefore, as requested by USAAVLABS, the preliminary 8 individual punched tape programs were revised to 3 punched tape programs which contained those selected components to be analyzed during flight line operation. This revision provided the following program tapes for the UH-1 helicopter engine and power train system:

Tape No. 109	Transmission and tail rotor components
Tape No. 110	Engine components
Tape No. 111	Selected transmission bearings not included in Tape No. 109

Correlation of Analyzer Indications and Mechanical Condition

Data Acquisition

A continuation of the field application program using the CWEA-4 analyzer was initiated on 10 July 1967. The objective of this phase of the program was to correlate the analyzer indications with the actual mechanical condition of the components, thereby permitting an evaluation of the established gain settings relative to the criteria selected to be used as indicators of the level of mechanical condition. This program was limited to the transmission and to the 42-degree and 90-degree tail rotor gear boxes on the model UH-1B helicopters. The Army authorized a teardown inspection of one to six of each of these assemblies based on three consecutive analyzer indications of abnormal signal characteristics at 10-hour (minimum) intervals.

The components of the transmission and tail rotor drive train selected for analysis during this program were those presented in Table LVII, which were programmed on a single punched paper tape. During the previous phase of this program, a refinement in the gain settings of some of these components was indicated, and these revised gain settings are also tabulated in Table LVII.

The UH-1B helicopters were analyzed at random in an effort to select those system components whose levels deviated from normal, thus qualifying for the teardown inspection. After these components were identified for a given aircraft, efforts were made to obtain repeat analysis. Since the majority of the helicopters analyzed during this program were taken from the training school helicopters on the line, the scheduling of these aircraft for repeat runs and for re-analysis often exceeded the 10-hour intervals specified. In addition, the regular 100- and 300-hour maintenance inspections limited the availability of some candidates.

A summary of the data obtained on the UH-1B helicopters analyzed for this phase of the field application program is given in Table LVIII. The component item numbers correspond with the item numbers in Table LVII. The historical data on the helicopters summarized in Table LVIII are given in Tables XLI and XLII for the engine and helicopter power train components, respectively. Some of the helicopters listed in Table LVIII were also analyzed using the previous individual program tapes. It is also noted that all of the data presented in Table LVIII were based on playback of the recorded data taken during operation of each helicopter.

Teardown Inspection

A review was made of the data obtained on the model UH-1B helicopters analyzed with the single program tape (Table LVII) for the transmission and tail rotor drive components in an effort to select candidates for the teardown inspection. The basis for selection was high-amplitude signals on bearings and gears plus relatively high amplitude sidebands or harmonics on gears that appeared on repeat analysis.

The following transmissions and the 42-degree and 90-degree tail rotor gear boxes were selected for teardown inspection and were shipped to the U. S. Army Aeronautical Depot Maintenance Center (ARADMAC) at the U. S. Naval Air Station, Corpus Christi, Texas. The components in each assembly and the reason for rejection are listed below with the results of the disassembly inspection at ARADMAC; these data are also summarized in Table LIX.

Transmission Serial Number A12-618

This transmission was removed from model UH-1B helicopter serial number 61-0745 and had 411 hours since last overhaul (1511 total hours). The component selected for inspection was the lower bevel drive gear train (items 15, 16 and 17, Figure 6), which displayed a

high-amplitude second harmonic signal relative to the fundamental amplitude signal; i.e., the second harmonic signal was greater than one-half the amplitude of the fundamental signal. However, the fundamental signal was relatively low compared to a normal signal; consequently, this criterion may not be valid under these conditions. Other components which were suspected based on single-analysis high-amplitude signals (not repeated on the repeat analysis) were the upper planetary gears (items 10, 11 and 12, Figure 6) due to high-amplitude second harmonic, the input bevel gears (items 1, 2 and 3, Figure 6) due to a high fundamental, upper main shaft support bearing (item 37, Figure 6) due to a high $3f_B'$, and lower main shaft support bearing (item 39, Figure 6) due to a high f_B'.

Visual inspection during disassembly indicated that all gears were within acceptable wear limits, and tooth contact patterns appeared to be normal. The triple row input quill shaft support bearing (item 24, Figure 6) had two calls with surface wear, and the outer race of one of the bearings showed evidence of pitting and corrosion. The outboard bearing showed evidence of the race spinning in the housing. The generator inboard quill shaft bearings (item 28, Figure 6) showed balls pitted and scratched. Unfortunately, an acoustic analysis of this bearing was not made because it was not included on the program tape. All other bearings appeared satisfactory based on visual inspection.

Transmission Serial Number A12-801

This transmission was removed from model UH-1B helicopter serial number 61-0730 and had 975 hours since the last overhaul (2060 total hours). The component selected for inspection was the upper planetary gear train (items 10, 11 and 12, Figure 6) on the basis of high-amplitude fundamental signals; i.e., a condition meter reading greater than eight at the established gain setting. A spectrogram of this transmission showing the upper planetary gear train is presented in Figure 25, and the corresponding frequency range spectrogram of a normal transmission is shown in Figure 26. Other components which were suspected based on single-analysis high-amplitude signals (not repeated on repeat analysis) were the lower bevel drive gears (items 15, 16 and 17, Figure 6) due to high-amplitude fundamental and relatively high amplitude second harmonic, the main input bevel gears (items 1, 2 and 3, Figure 6) due to high-amplitude fundamental, the lower output quill shaft double row bearing (item 43, Figure 6) due to high f_2 and f_B', and the upper planetary support bearing (item 36, Figure 6) due to high-amplitude $3f_B'$.

The teardown inspection indicated a heavy wear pattern on the upper planetary sun gear (item 10, Figure 6) and a chip on one gear tooth. Visual inspection of all other gears showed tooth contact patterns to be normal and within acceptable wear limits. All bearings appeared to be satisfactory. The discovery of an unmodified plastic plug in the lower output bevel gear shaft restricting oil flow used for gear lubrication indicated that oil starvation had occurred. Although gear wear pattern was considered normal, lack of proper lubrication under certain conditions may have been responsible for the high-amplitude signal observed.

Transmission Serial Number B12-613

This transmission was removed from model UH-1B helicopter serial number 62-1964 and had 806 hours since new (no overhauls). The components selected for inspection were the lower bevel drive gear train (items 15, 16 and 17, Figure 6) and the main input drive bevel gear train (items 1, 2 and 3, Figure 6), due to high-amplitude fundamental signals. The lower bevel drive gears also displayed relatively high second harmonic signals. A spectrogram of this transmission showing the lower bevel drive gear train is presented in Figure 27, and a normal spectrogram is shown in Figure 26. Other components which were suspected on the basis of having high-amplitude signals (not repeated on repeat analysis) were (1) the upper planetary gears (items 10, 11 and 12, Figure 6) which displayed high fundamental signals and relatively high second harmonic signals, (2) the upper main shaft support bearing (item 37, Figure 6) which displayed high f_2 and $3f_B'$ signals, (3) the single row input quill shaft bearing (item 23, Figure 6) which displayed a high $3f_B'$ signal, (4) the lower output quill shaft double row bearing (item 43, Figure 6) which displayed high f_2 and $3f_B'$ signals, and (5) the lower input quill shaft single row bearing (item 41, Figure 6) which displayed high f_B' and $3f_B'$ signals.

Visual inspection during disassembly indicated that all gear tooth contact patterns were normal and were within acceptable wear limits. All bearings appeared to be satisfactory with the exception of the lower output quill shaft single-row bearing (item 42, Figure 6), which had a rough spot on the outer race. Unfortunately, this bearing was not analyzed prior to the teardown inspection.

42-Degree Gear Box Serial Number B13-4313

This gear box was removed from model UH-1B helicopter serial number 61-0745 and had 832 hours since new (no overhauls). The component selected for inspection was the bevel gear set (items 50 and 51, Figure 9) which displayed sideband signals which were half the amplitude of the fundamental signal. Although this is the criterion established for an abnormal component, the low amplitude of the fundamental together with the marginal amplitude of the sidebands may give an erroneous indication. A spectrogram of this 42-degree gear box showing the bevel gear train is presented in Figure 28, and the corresponding frequency range spectrogram of a normal gear box is shown in Figure 29.

Visual inspection during disassembly indicated that the bevel gear tooth contact patterns appeared normal and were within acceptable wear limits. All bearings appeared to be satisfactory.

42-Degree Gear Box Serial Number B13-2556

This gear box was removed from model UH-1B helicopter serial number 61-0730 and had 89 hours since new (no overhauls). The component selected for inspection was the bevel gear set (items 50 and 51, Figure 9) due to higher than normal amplitude fundamental signals. These signals were just above the reject level (condition meter level greater than eight). This gear box was removed to correlate the mechanical condition with these marginal signal indications. The confirmation or nonconfirmation of these signal indicators will assist in establishing the final analyzer limits. A spectrogram of this 42-degree gear box showing the bevel gear train is presented in Figure 30. A comparison of this spectrogram with the normal spectrogram shown in Figure 29 shows the high-amplitude signal of the bevel gear. The single-row quill shaft support bearing (item 42, Figure 9) was suspect due to a high $3f_B'$.

The teardown inspection indicated that the bevel gears were within acceptable wear limits and tooth contact patterns based on visual inspection. All bearings appeared satisfactory based on visual inspection.

90-Degree Gear Box Serial Number A13-208

This gear box was removed from model UH-1B helicopter serial number 61-0724 and had 346 hours since new (no overhauls). The component selected for inspection was the bevel gear set (items 52 and 53, Figure 9) due to high-amplitude fundamental signals. A spectrogram of this 90-degree gear box showing the bevel gear train is presented in Figure 31, and the corresponding spectrogram of a normal 90-degree gear box signal is shown in Figure 29. Figure 31 shows the high-amplitude bevel gear signal as compared with the normal-amplitude signal depicted in Figure 29.

The teardown inspection revealed a loss of metal from the load side teeth of the driven gear. The teeth on this gear were considered to be worn beyond acceptable limits and were not repairable. The tooth contact pattern on the drive gear was considered marginal; however, this gear could be salvaged by dressing the gear teeth.

All bearings appeared satisfactory based on visual inspection.

90-Degree Gear Box Serial Number B13-4108

This gear box was removed from model UH-1B helicopter serial number 61-0745 and had 832 hours since new (no overhauls). The component selected for inspection was the bevel gear set (items 52 and 53, Figure 9) due to relatively high amplitude sideband signals. A spectrogram of this 90-degree gear box showing the bevel gear train is presented in Figure 28, and the corresponding normal spectrogram is shown in Figure 29. Figure 28 shows the relatively high sidebands accompanying the fundamental signal as compared with no sidebands in Figure 29.

The teardown inspection revealed high tooth wear on both gears. The drive gear had pits on the load side of two teeth and was not repairable. The driven gear could possibly be salvaged by rework and accepted through material review action in an emergency situation if an acceptable tooth contact pattern were obtained when installed with a new drive gear.

All bearings appeared satisfactory based on visual inspection.

90-Degree Gear Box Serial Number A13-206

This gear box was removed from model UH-1B helicopter serial number 61-0730 and had 89 hours since new (no overhauls). The component selected for inspection was the bevel gear set (items 52 and 53, Figure 9). The amplitude of the fundamental and sideband signals was inconsistent among the three analyses made on this gear box, and the inspection was considered desirable in an effort to determine the possible causes of these discrepancies. Spectrograms made of the bevel gear signals for each of these analyses were also inconsistent. However, one of the spectrograms (see Figure 30) showed a very high amplitude bevel gear signal as compared with the normal signal shown in Figure 29. This high signal also corresponded to a high analyzer indication.

The teardown inspection revealed that the tooth contact pattern was marginal for the relatively low time (89 hours) on the gear box. Although the pattern was within acceptable limits for an in-service unit, it would not be acceptable for a new or overhauled unit.

All bearings appeared satisfactory based on visual inspection.

Analysis of Teardown Inspection Results

Transmission

The indicators for an abnormal condition on the upper main rotor planetary gears (items 10, 11 and 12, Figure 6), the lower output bevel gears (items 15, 16 and 17, Figure 6), and the input bevel gears (items 1, 2 and 3, Figure 6) have been high fundamental signals (condition meter reading greater than eight at the established gain setting) or a second harmonic signal greater than one-half of the fundamental at the fundamental gain setting. Based on the results of the teardown inspection, these indicators do not appear to be valid for the lower output bevel gears or the input bevel gears from the standpoint of excessive gear tooth wear or improper gear tooth contact patterns, particularly the indicator of the second harmonic higher than one-half of the fundamental at low fundamental amplitudes. At low fundamental signals, the harmonic signals observed may be only random noise. However, in one case in which the analyzer rejected the lower output bevel gears and there was no confirmation of a mechanical malfunction, there was a discrepancy noted during teardown which may be associated with the gear signals. This discrepancy detected on transmission serial number B12-613 (model UH-1B helicopter serial number

62-1964) indicated a lack of proper lubrication supplied to the bearing supporting one of the lower output bevel gears. It is therefore conceivable, based on previous experience, that this deficiency in the bearing lubrication may be reflected in the function of the bevel gear and, consequently, may produce some abnormal signal characteristics.

Only one upper planetary gear train (transmission serial number A12-801, model UH-1B helicopter 61-0730) was selected as a primary component for inspection in the three transmissions disassembled, and the teardown inspection results revealed that the high fundamental signal observed is a valid indicator of a malfunction in this gear train. For the remaining two transmissions inspected, the upper planetary gear train was one of a secondary suspected component.

The indicator of amplitude only for the remaining gears and for the bearings (condition meter reading in excess of eight at the established gain setting) appears to be satisfactory on the basis that no abnormal condition was found on any of these parts during the teardown inspection and no consistently high amplitudes were detected by the analyzer on the repeat analysis.

Further investigation is needed to determine if the present indicators for the upper planetary gears, the lower output bevel gears, and the input bevel gears point to some other abnormal condition such as misalignment, eccentricity, unbalance, or improper gear tooth preload.

A possible example of these abnormal conditions was exhibited by model UH-1B helicopter serial number 62-4604, which was rejected for flight several times because of high vibration. An analysis of this aircraft (on 19 July 1967) using the CWEA-4 analyzer revealed no abnormal signals in either the engine or the helicopter power train components except for the transmission input quill shaft bearing (item 23, Figure 6). Since the analyzer indication was the only clue to any discrepancy, the input quill shaft assembly was replaced. Unfortunately, this was completed before another analyzer check could be made. The aircraft was checked out following this change and was approved for flight. No further complaints were noted. Unfortunately, the tight flying schedule and a 100-hour inspection prevented another check of this aircraft prior to its transfer to another base. A visual inspection of the quill shaft assembly revealed no apparent discrepancy, and this unit was sent to ARADMAC for a complete teardown inspection. No report from ARADMAC has been received on this unit. The fact that there were several vibration complaints registered by more than one pilot prior to removal of this quill shaft assembly and that there were no such complaints following this change is evidence that there

was some abnormality associated with this assembly. Such an abnormality could have been an installation misalignment of either the quill shaft or the adjoining shaft or some other unbalance condition or eccentricity. This discrepancy was apparently reflected in the bearing signal, which is not an unusual condition. Based on previous experience, defects in certain components can be reflected in the signal characteristics of mechanically connected components.

The correlation achieved between the analyzer indicator and the mechanical condition of the upper planetary gear (removed from transmission serial number A12-801, model UH-1B helicopter serial number 61-0730) substantiates the need for further analysis of the recorded data. In this case, a high fundamental frequency was used as the indicator of a malfunction. Thus, a revision in the gain settings may be the requirement, rather than the elimination of a high-amplitude signal, as an indicator of a discrepancy. In addition, consideration of sideband signals for the higher speed gears should be included in this investigation to determine if sidebands can be detected and to determine the meaning of any sidebands (sideband frequencies must differ from fundamental frequencies by 30 cycles or more to exceed the filter width frequency). Consideration of multiple harmonics (second, third, fourth and fifth) of the gear fundamentals should also be included in any further investigation to determine if an abnormal condition - a comparison of odd and even harmonics - may be the indicator.

42-Degree Gear Box

The indicators for an abnormal condition of the bevel gears (items 50 and 51, Figure 9) have been high fundamental signals (condition meter reading greater than eight at the established gain setting), sidebands, or second harmonic signals greater than one-half of the fundamental signals at the fundamental gain setting. Based on the results of the teardown inspection, these indicators do not appear to be valid for excessive gear tooth wear or improper gear tooth wear patterns. The combination of a second harmonic greater than one-half of the fundamental at low fundamental amplitudes in particular does not appear to apply as an indication of gear tooth condition.

The high-amplitude fundamental or high sideband and second harmonic signals in combination with a fundamental greater than five on the condition meter at the established gain level may be an indication of some abnormal condition other than gear tooth wear or pattern. Further investigation to relate these indicators to such things as excessive tail boom vibration and drive shaft eccentricity, unbalance, or misalignment should be undertaken.

The indicator for condition of the bearings in the gear box and also for the drive shaft bearings (item 46, Figure 9) has been amplitude (condition meter reading in excess of eight at the established gain setting). This indicator appears to be satisfactory on the basis that no abnormal condition was found on gear box bearings during the teardown inspection and that no consistently high amplitudes were detected by the analyzer on the repeat analysis. None of the drive shaft bearings were inspected, since no consistently high signals were noted.

90-Degree Gear Box

The indicator for an abnormal condition on the bevel gears (items 52 and 53, Figure 9) and the gear box bearings has been the same as for the 42-degree gear box. Based on the results of the teardown inspection, these indicators for the condition of the gear teeth appear to be satisfactory, since all gears showed signs of abnormal conditions. The excellent correlation between the analyzer indicator (high fundamental signal) and the mechanical condition of the bevel gear removed from the 90-degree gear box (serial number A13-208, model UH-1B helicopter serial number 61-0724) substantiates these indications. Also, the good correlation between the analyzer indicator based on amplitude of sidebands and the mechanical condition of the bevel gear removed from the 90-degree gear box (serial number A13-206, model UH-1B helicopter serial number 61-0730) substantiates the use of sideband signals as a valid indicator of 90-degree gear box malfunctions. The indicator for the double-row bearing in this gear box also appears satisfactory, since no bearing abnormalities were found and no consistently high signals were noted. The double-row bearings in both the 42- and 90-degree gear box are identical and operate at the same speed. Since a single microphone is used for both gear boxes, the same indicator applies to all of these bearings. The condition of the single-row bearing in the 90-degree gear box has not been monitored by the analyzer, since it was not included on the program sheet. The fact that these bearings were found to be satisfactory in all of the gear boxes inspected will be of value in establishing the gain setting for this bearing for future use.

Analyzer Performance

During the period of 28 June to 15 September 1967, the CWEA-4 Sonic Analyzer was in operation at Fort Rucker, Alabama, and no major performance or operational problems were encountered with the analyzer. The analyzer was operated approximately 30 minutes on battery power for each live analysis with the batteries placed on charge approximately four hours each day. All playback analysis of the recorded data was performed using 110-volt AC power with the power selector switch placed in the "line/charge" position.

During a live analysis on 8 September 1967, it was noted that operation of the paper tape reader drive motor became sluggish, and it became necessary to complete the analysis using the manual mode of operation. Subsequent investigation revealed that the current limiting resistor in the battery charging circuit had failed, and therefore the batteries were not receiving a charging current. The sluggish operation of the drive motor was a direct result of the reduction in battery output voltage. Further investigation revealed that 4 of the 38 batteries had failed, causing the resistor failure as a result of a higher than normal charging current. The battery failure was considered to be a random failure and was not entirely unexpected due to the relatively high number of hours that these batteries have been in use and the relatively high current drain required for operation of the analyzer. The analyzer downtime required to troubleshoot the problem, to locate the failed batteries, and to replace the resistor and the four batteries was approximately 2 hours. Operation of the analyzer using 110-volt AC was not affected by the battery failure.

The other maintenance performed on the analyzer was cleaning of the tape reader unit, particularly in the area of the exposed switches. This maintenance required approximately 1 hour, and no parts were replaced.

A routine inspection was also made on the analyzer at the completion of the Fort Rucker operation to determine if the analyzer and microphone systems were within operating tolerances. This check indicated that all adjustments were within specification. The time required to make this check was approximately one-half hour.

The operational experience with the CWEA-4 analyzer was primarily on the model UH-1B helicopters. No problems were encountered in the setting of engine speeds at 60 ± 2% for N_1 and 4500 ± 100 rpm for N_2 (transmission input quill shaft speed) necessary for operation of the analyzer. Satisfactory locks for both N_1 and N_2 were obtained for the majority of the UH-1B helicopters analyzed at Fort Rucker. The operating experience on the model UH-1A, UH-1C, and UH-1D helicopters was not as extensive as on the UH-1B; however, no major operational or lock problems are anticipated on these models. A small shift in the set speeds on model UH-1D helicopters may be necessary in the future to more nearly match the flight idle speeds for this particular model helicopter.

Training Program

Instruction in the operation of the CWEA-4 analyzer that included live analysis on the model UH-1B helicopter and playback analysis of the recorded data was given to the following types of personnel at Fort Rucker, Alabama. All of these personnel were employed by Page Aircraft Maintenance, Inc. (PAMI), the primary maintenance contractor for the UH-1 helicopters at Fort Rucker:

Training Instructor (1)	PAMI Headquarters
Mechanics (2)	Lowe Field
Mechanic (1)	Knox Field
Mechanic (1)	Hanchey Field

The training instructor indicated that his group would have the responsibility for instruction of any PAMI personnel assigned to operate the CWEA-4 analyzer if it were placed in operation at Fort Rucker. No military personnel were trained in the operation of the analyzer, since they do not operate this type of equipment at Fort Rucker.

A training program was also conducted at Fort Eustis, Virginia, for personnel of USAAVLABS. This instruction included live operation on a UH-1 helicopter, playback analysis of recorded data, and electronic circuit theory and check-out.

MATERIAL DELIVERED

CWEA-4 Sonic Analyzer with UH-1 Helicopter Acoustic Plug-In Module

The model CWEA-4 analyzer with the UH-1 helicopter acoustic plug-in module was delivered to the Army on 24 June 1967 and is currently at USAAVLABS, Fort Eustis, Virginia.

Handbooks, Manuals and Engineering Drawings

The Operation and Maintenance Manual for the CWEA-3, -4 Sonic Analyzer dated July 1967, the Acoustic Handbook for the UH-1 helicopter complete system, and the engineering drawings were delivered to the USAAVLABS on 21 November 1967.

CONCLUSIONS

The Curtiss Model CWEA-4 Sonic Analyzer shows good potential as a successful indicator of power train component anomalies for the model UH-1A, UH-1B, UH-1C, and UH-1D helicopters based on the satisfactory performance and operational characteristics exhibited during the field application program. The conclusions derived from this field program include the following:

1. The correlation between the CWEA-4 analysis and the spectrograms produced on a standard wave-form analyzer was very good for the engine, transmission, and tail rotor components inspected.

2. The correlation between the CWEA-4 analysis and the mechanical condition of the 90-degree gear box power train components was excellent.

3. The correlation between the CWEA-4 analysis using existing indicator criteria and the mechanical condition of the 42-degree gear box power train components was not confirmed by the teardown inspection. However, it may be concluded, based on past experience with similar types of gear boxes, that these criteria are valid indicators of some system abnormality, [illegible] directly related to the mechanical condition of the component, such as structural vibration, component misalignment, or shaft unbalance or eccentricity.

4. The correlation between the CWEA-4 analysis and the mechanical condition of the main rotor transmission power train components was confirmed in the case of the upper planetary gear train; however, there were no positive confirmations of the other transmission gears inspected. Again, the analyzer results were substantiated by spectrogram presentation, which warrants further investigation of these components to establish better criteria for detecting abnormal conditions. A more extensive analysis of the sideband activity and the harmonic content of the transmission gear signals will be required to establish these criteria.

5. The CWEA-4 analysis showed no positive indications of any bearing discrepancies based on repeat analysis, and the teardown inspection revealed no bearing rejects on those selected for analysis.

6. No major problems were encountered in the operation of the analyzer during the field application program.

For future programs, the following items should be considered:

1. Perform a sonic analysis on a selected group of UH-1 helicopters 50 hours prior to each 300-hour inspection period. This analysis should be repeated at least twice prior to the scheduled inspection on any suspect components to confirm the identity of these components and to insure against random indications that cannot be repeated.

2. Maintain a record of the helicopters analyzed along with the condition meter readings for the components analyzed as a basis for showing indications of a deterioration of any component with time and also as a basis for future readjustment of the component gain settings if required. This record will also be of value for review in case of later removal of an abnormal component that had not previously been detected by the analyzer.

3. To provide flexibility in the use of the analyzer, the analyzer should be mounted in an enclosed powered vehicle so that it can be readily driven to the helicopter to be analyzed. A take-up reel should be provided for the microphone cable, which should have a minimum length of 50 feet.

4. Determine if the engine speeds established for analysis of the UH-1 helicopters are valid for the model UH-1D helicopter.

5. Identify the source of abnormal acoustic signals not confirmed by teardown inspection.

6. Perform a more extensive investigation of a selected list of components which exhibit a history of chronic failures.

7. The method of setting the engine N_1 and N_2 speeds at 60% and 4500 rpm, respectively, should possibly be revised as follows:

    a. The engine N_1 speed should be based on a certain given torque value at 60% speed.

    b. The 4500 rpm setting for the engine N_2 (transmission input shaft) is satisfactory.

RECOMMENDED DESIGN CHANGES

The performance of the analyzer may be enhanced for future applications by incorporation of the following design changes:

1. Modify the intermediate frequency amplifier to obtain better dynamic range.

2. Weatherproof microphones and microphone cable to permit operation under adverse weather conditions.

3. Provide fixed light on analyzer or an overhead light in transport vehicle to permit night operation of analyzer.

4. Increase speed of paper tape reader when on "full automatic" in order to reduce live analysis running time to approximately 10 minutes for a 60-component analysis. Elimination of the present two-step operation per component should be considered.

5. Provide take-up reels for the automation tapes, either hand wound or driven by the tape reader motor.

6. Provide a momentary switch that will offset the component select ratio by approximately $\pm$ 0.0015 to confirm that a high signal is a true discrete signal rather than random noise (manual or automatic operation). Also, provide a second momentary switch that will reduce the gain by 5 and 10 db to determine the strength of any "peg" signals.

7. Eliminate shift on locking signal between N_1 and N_2 for each advance of the automation tape.

8. Provide a more positive indication of locking to the proper signal. The present lock light and rpm meter are not adequate to insure that a proper lock is being maintained during analysis.

9. Program the "calibrate" function to include automatic turn-on of the tuning fork oscillator rather than relying on manual turn-on. This switch has been left in the "off" position numerous times when attempting to set the center frequency.

10. Eliminate the rpm meter hysteresis and center frequency hysteresis when shifting from a N_1 to N_2 lock. Also, eliminate the center frequency drift with temperature.

11. Increase battery capacity. Present batteries permit approximately three analyses of 15 minutes each when starting with fully charged batteries.

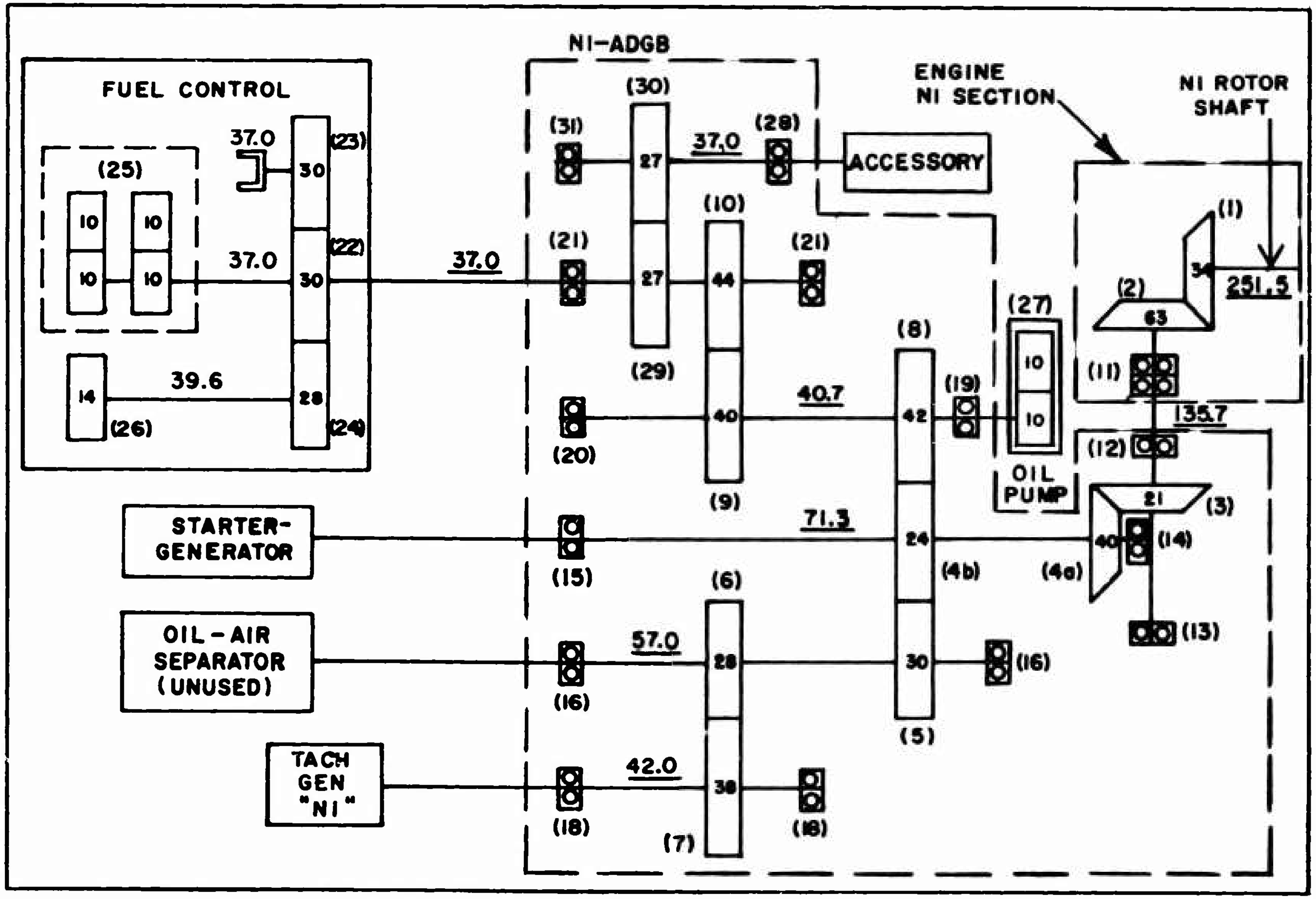

Figure 1. Gear Train Schematic - Model T53-L-1A Engine - Gas Producer Section (N_1).

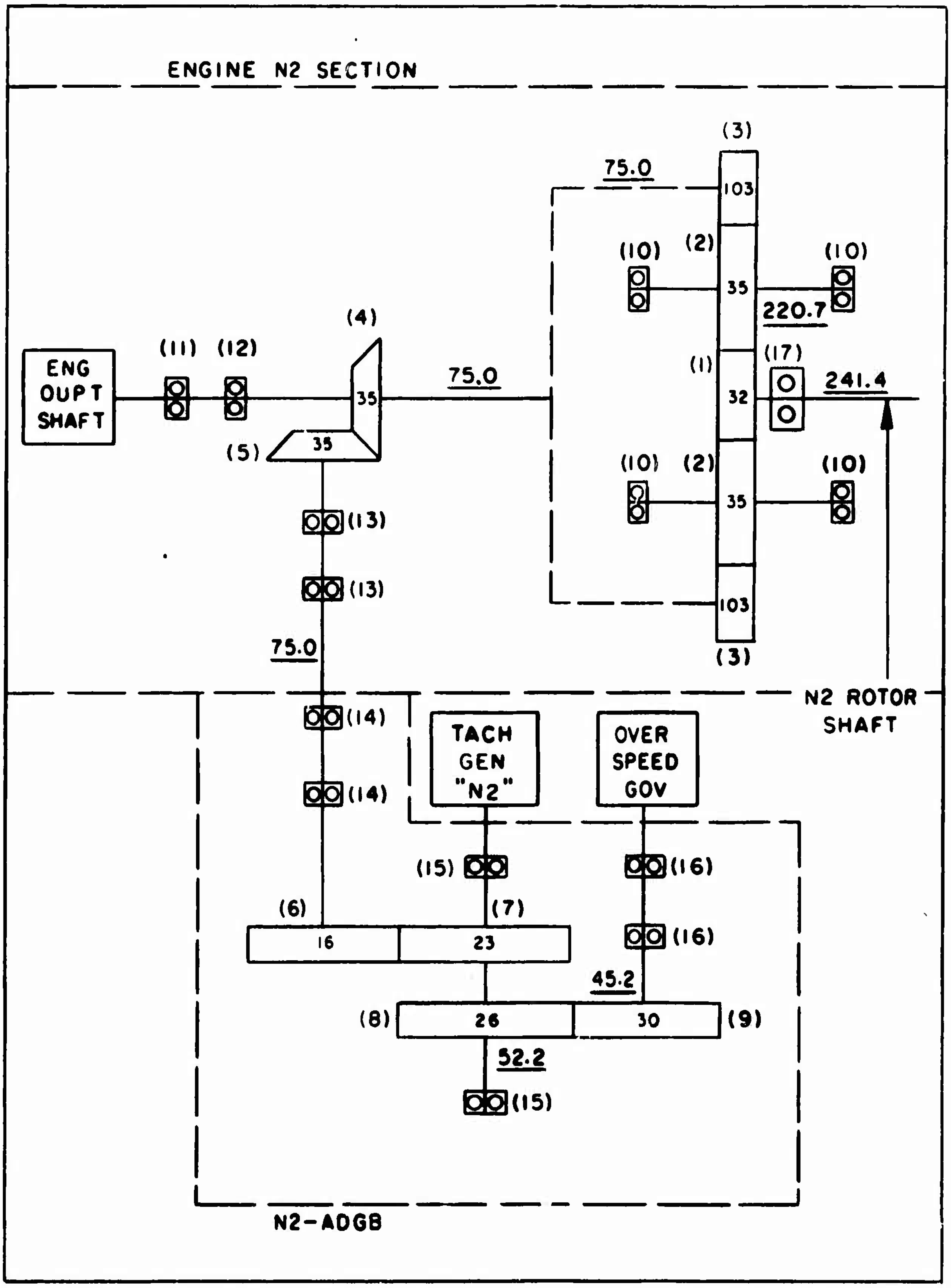

Figure 2. Gear Train Schematic - Model T53-L-1A Engine - Power Turbine Section (N_2).

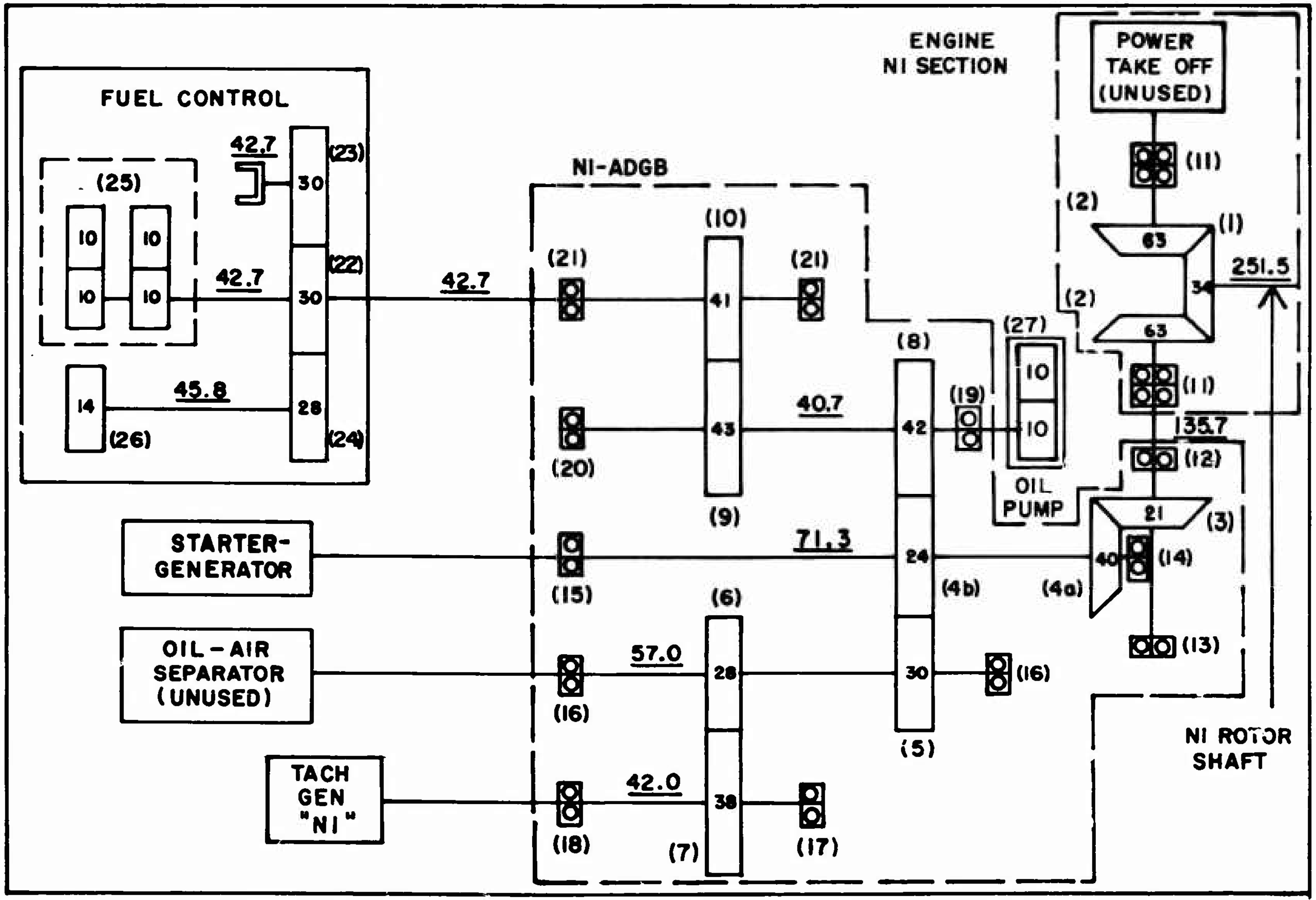

Figure 3. Gear Train Schematic - Models T53-L-9, T53-L-9A, and T53-L-11 Engines - Gas Producer Section (N_1).

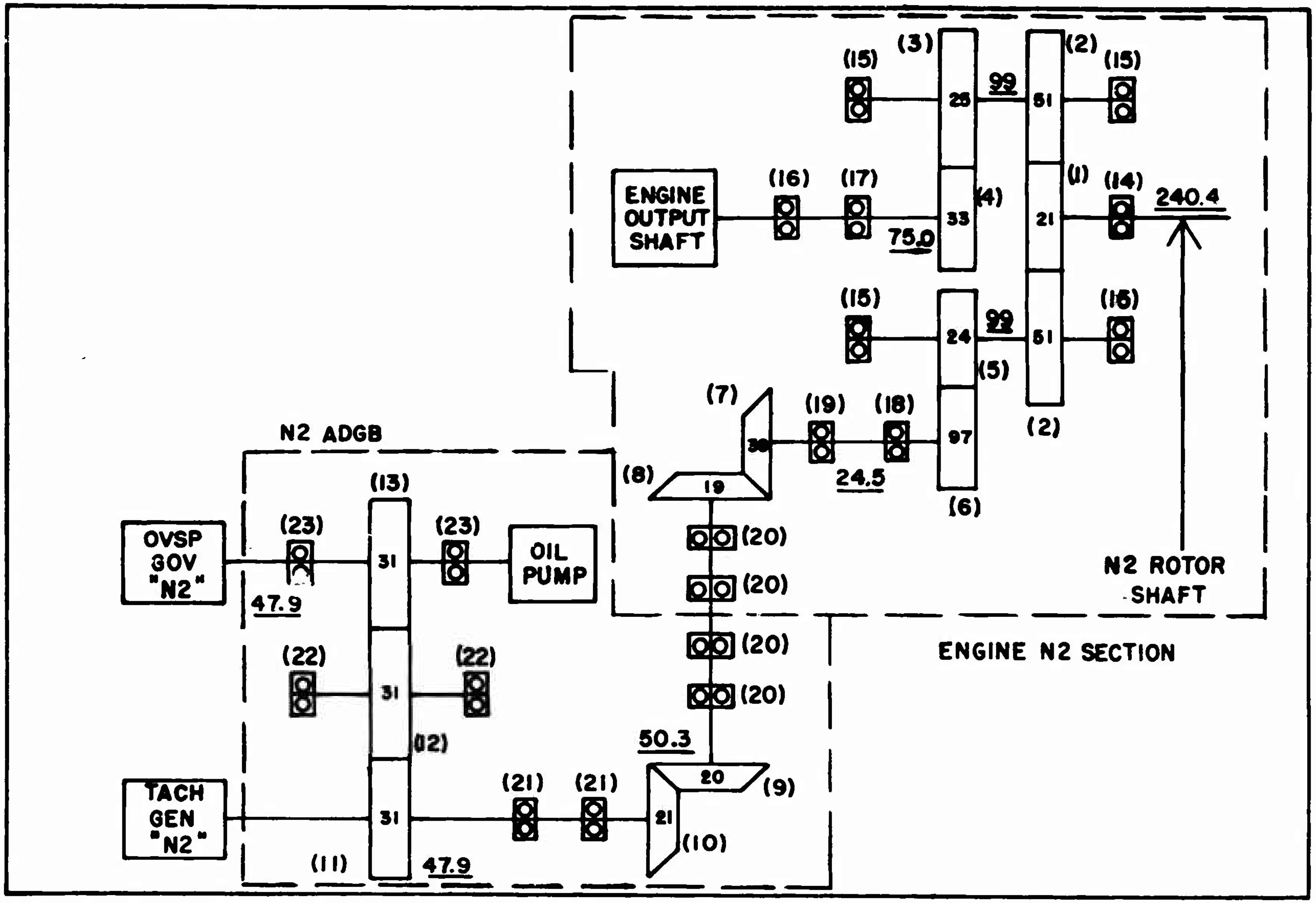

Figure 4. Gear Train Schematic - Models T53-L-9, T53-L-9A, and T53-L-11 Engines - Power Turbine Section (N_2).

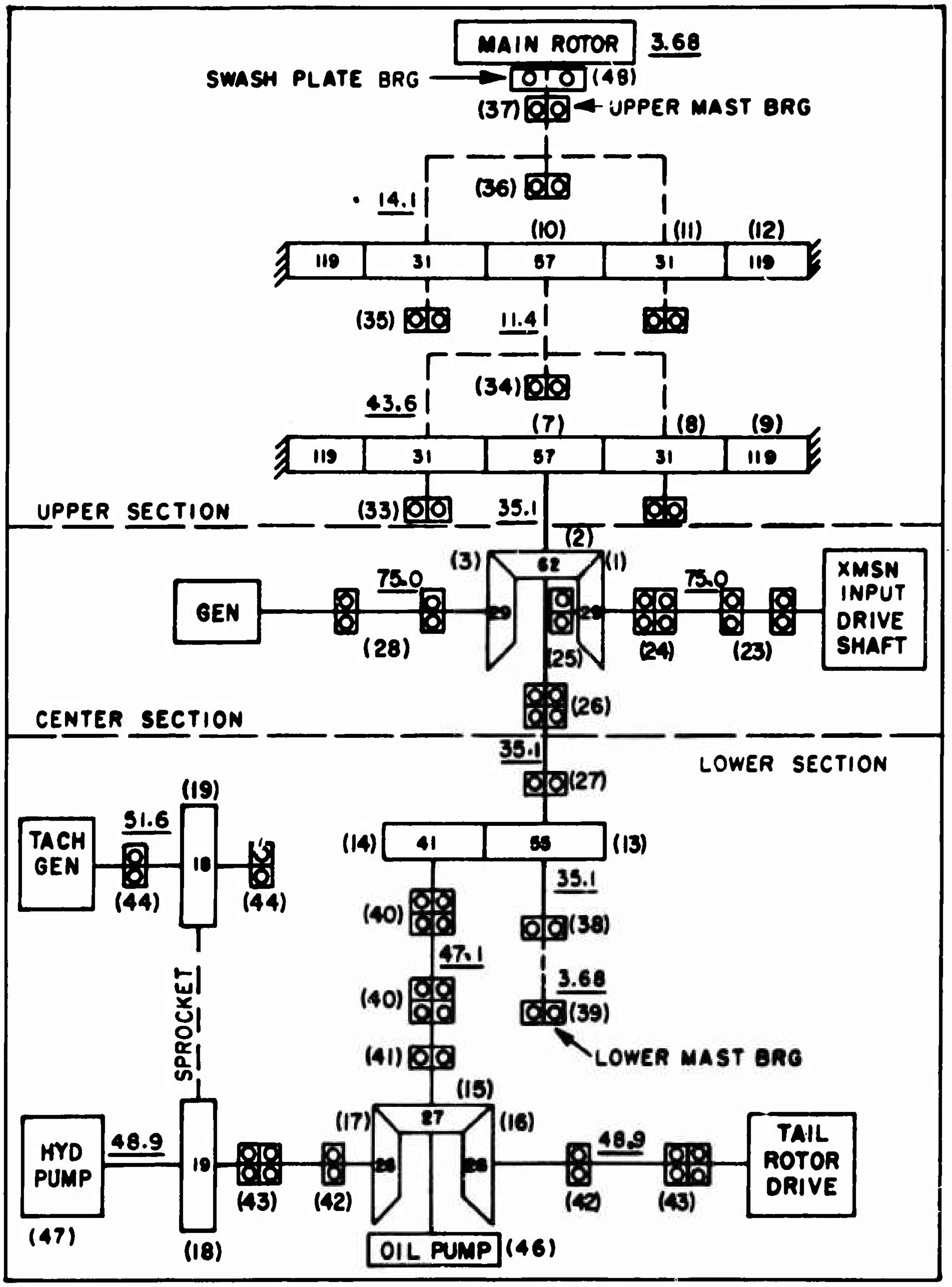

Figure 5. Gear Train Schematic - Model UH-1A Helicopter Main Rotor Transmission.

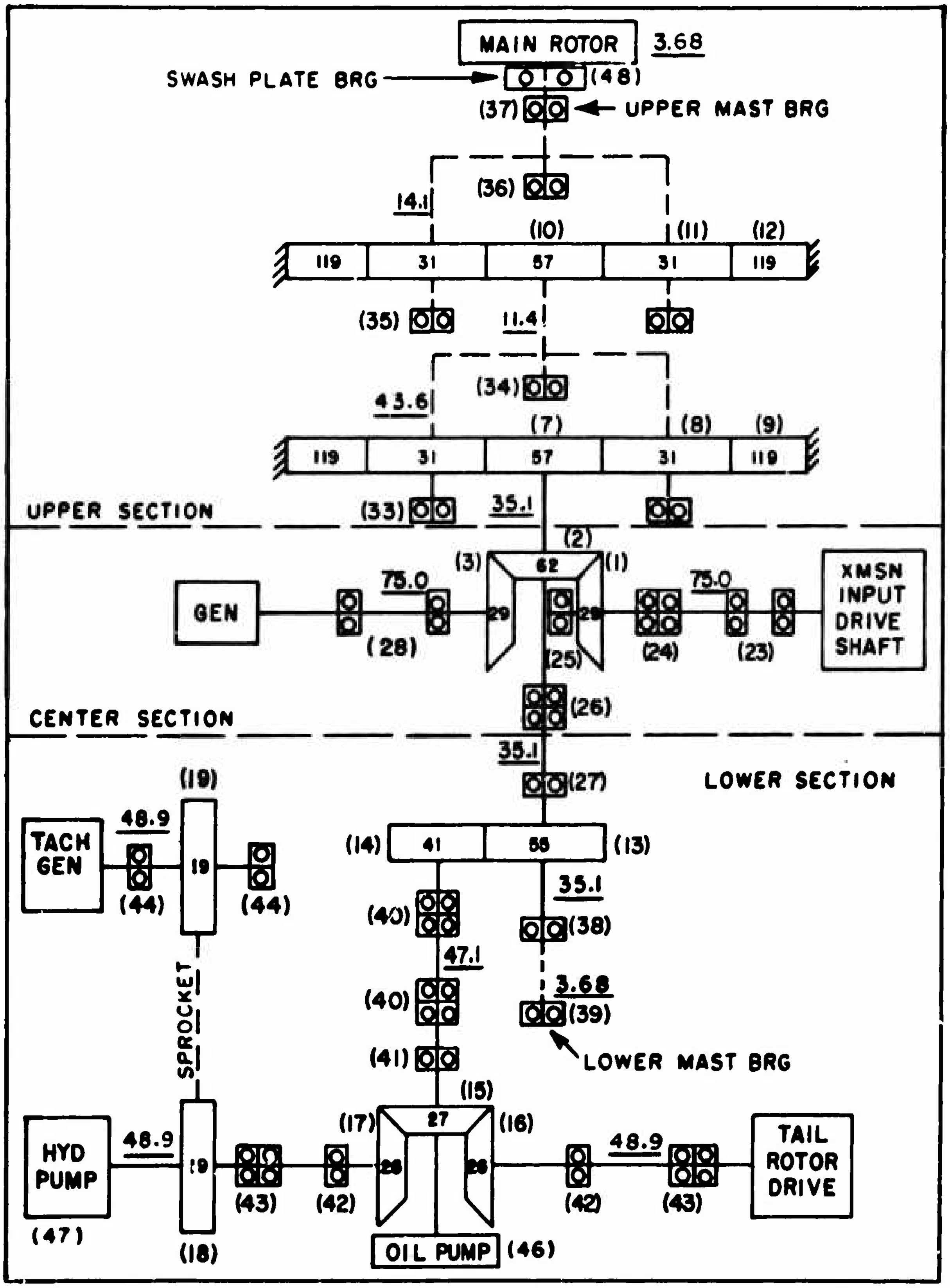

Figure 6. Gear Train Schematic - Model UH-1B Helicopter Main Rotor Transmission.

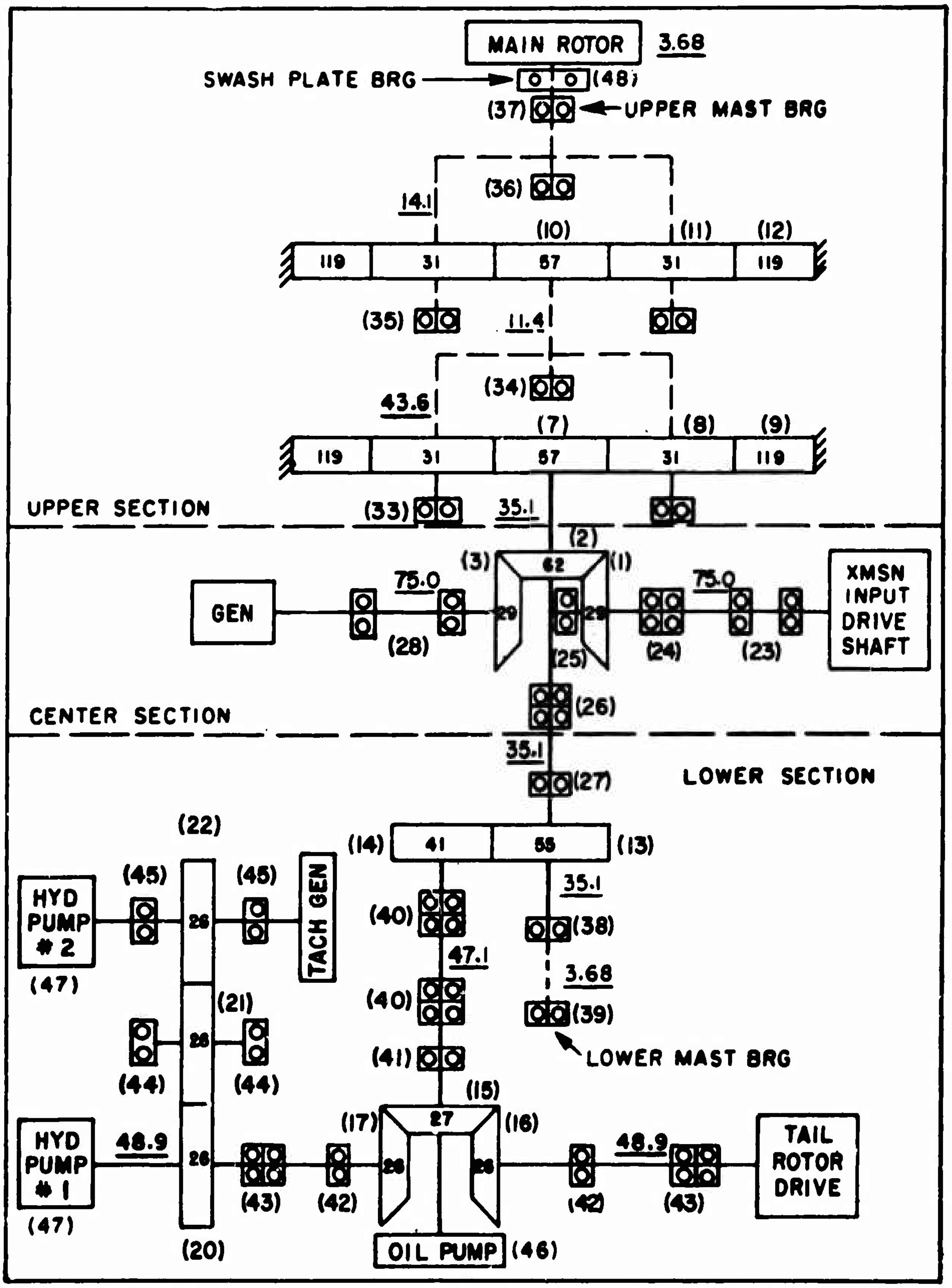

Figure 7. Gear Train Schematic - Model UH-1C Helicopter Main Rotor Transmission.

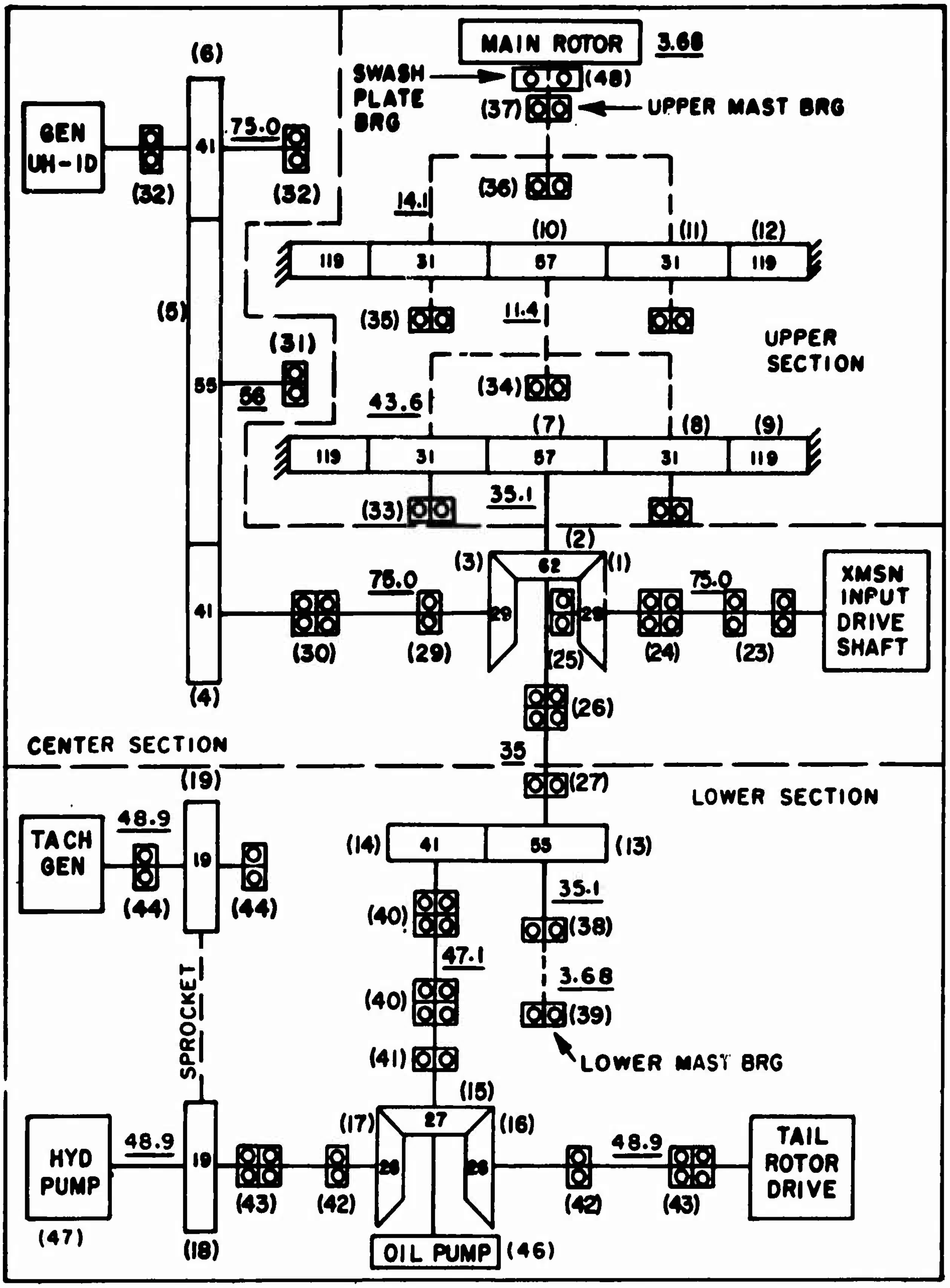

Figure 8. Gear Train Schematic - Model UH-1D Helicopter Main Rotor Transmission.

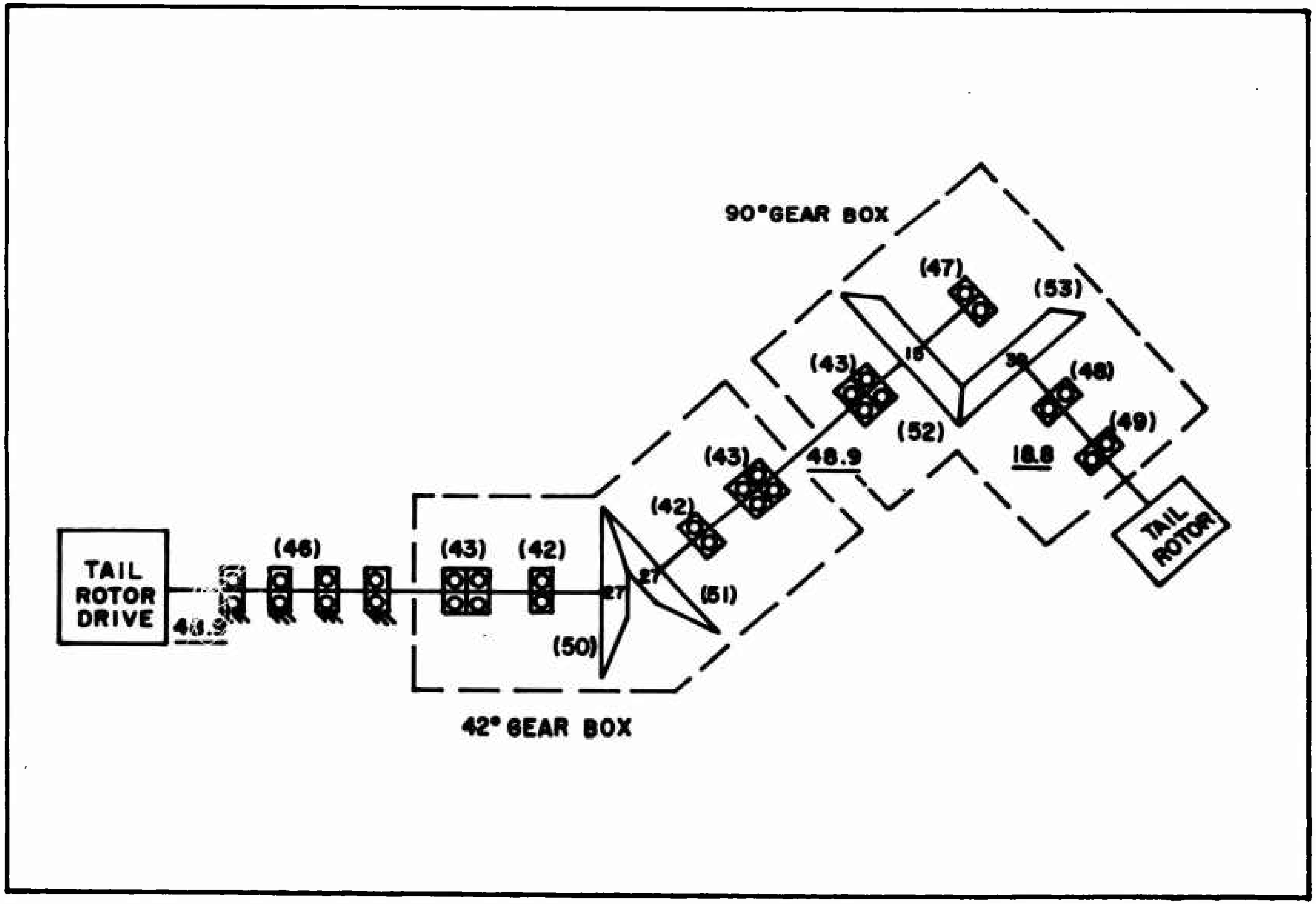

Figure 9. Gear Train Schematic - Models UH-1A, UH-1B, UH-1C, and UH-1D Helicopters Tail Rotor Gear Boxes.

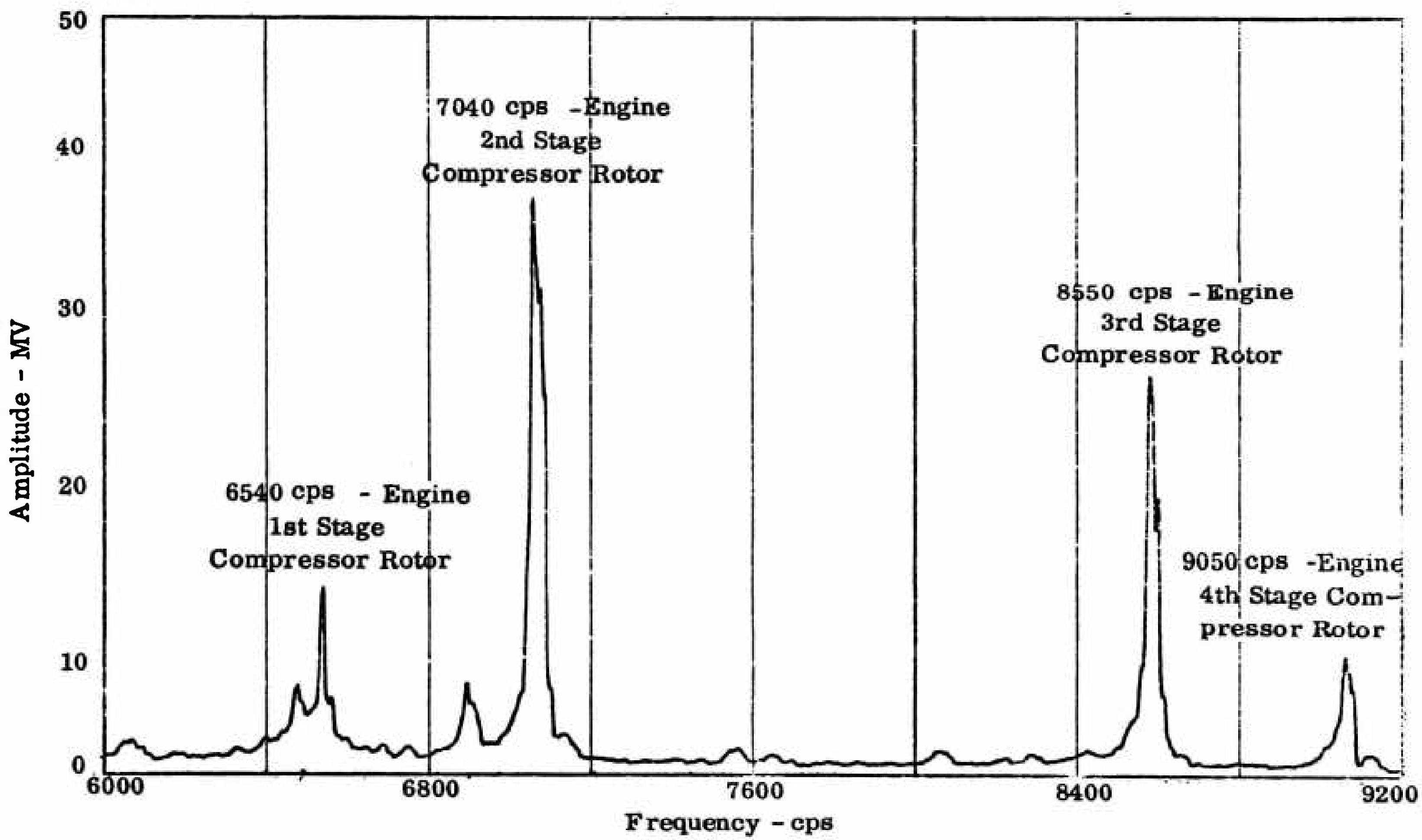

Figure 10. Amplitude vs. Frequency Spectrogram of Engine Compressor Signals (Transmission Microphone) - UH-1B Helicopter Serial Number 62-1925, Engine N1 Speed at 60%.

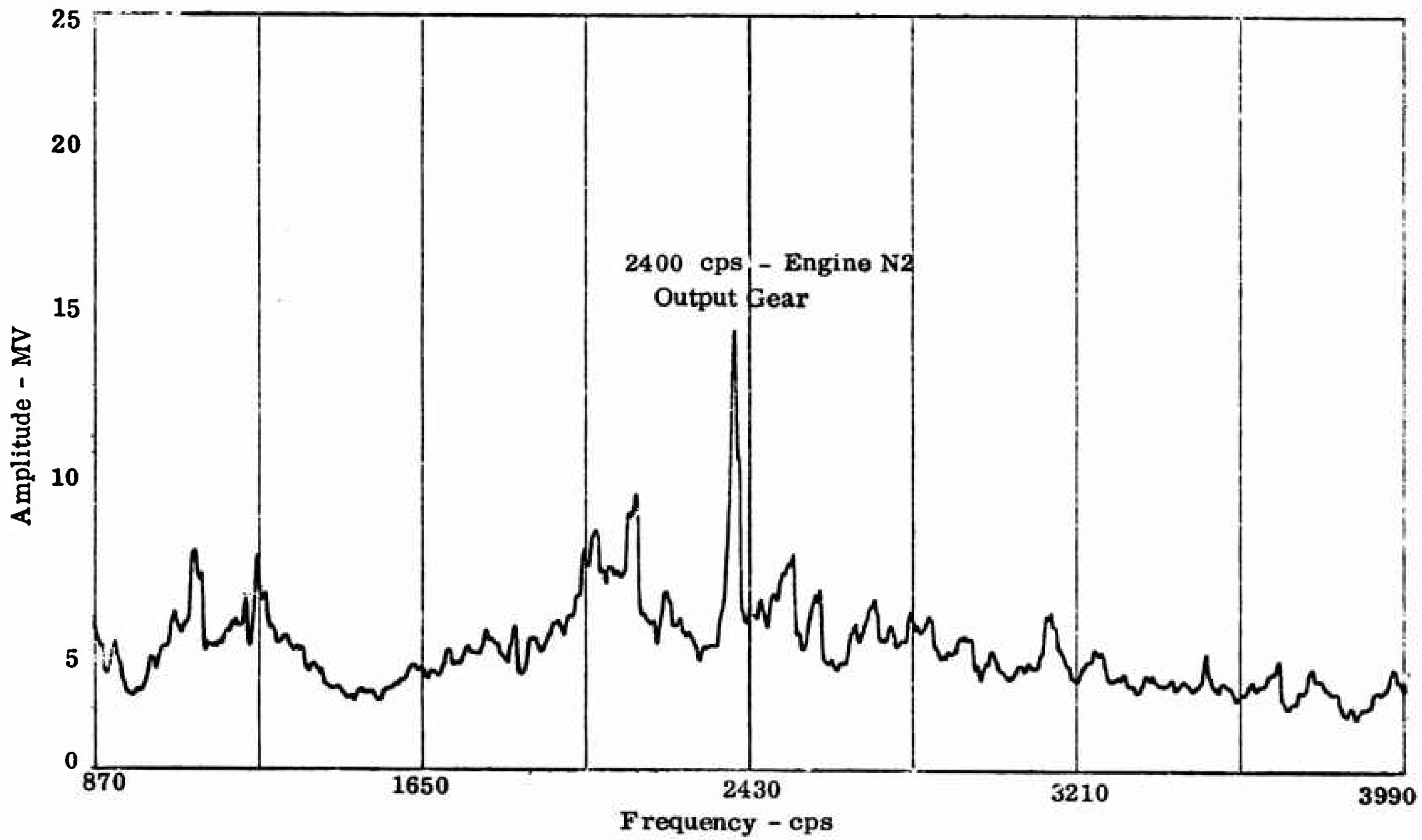

Figure 11. Amplitude vs. Frequency Spectrogram of Normal Engine Gear Signals (Engine Microphone) - UH-1B Helicopter Serial Number 62-1925 (T53-L-9A Engine Serial Number LE-06135, Engine N1 Speed at 60%, Engine N2 Speed at 66.3%).

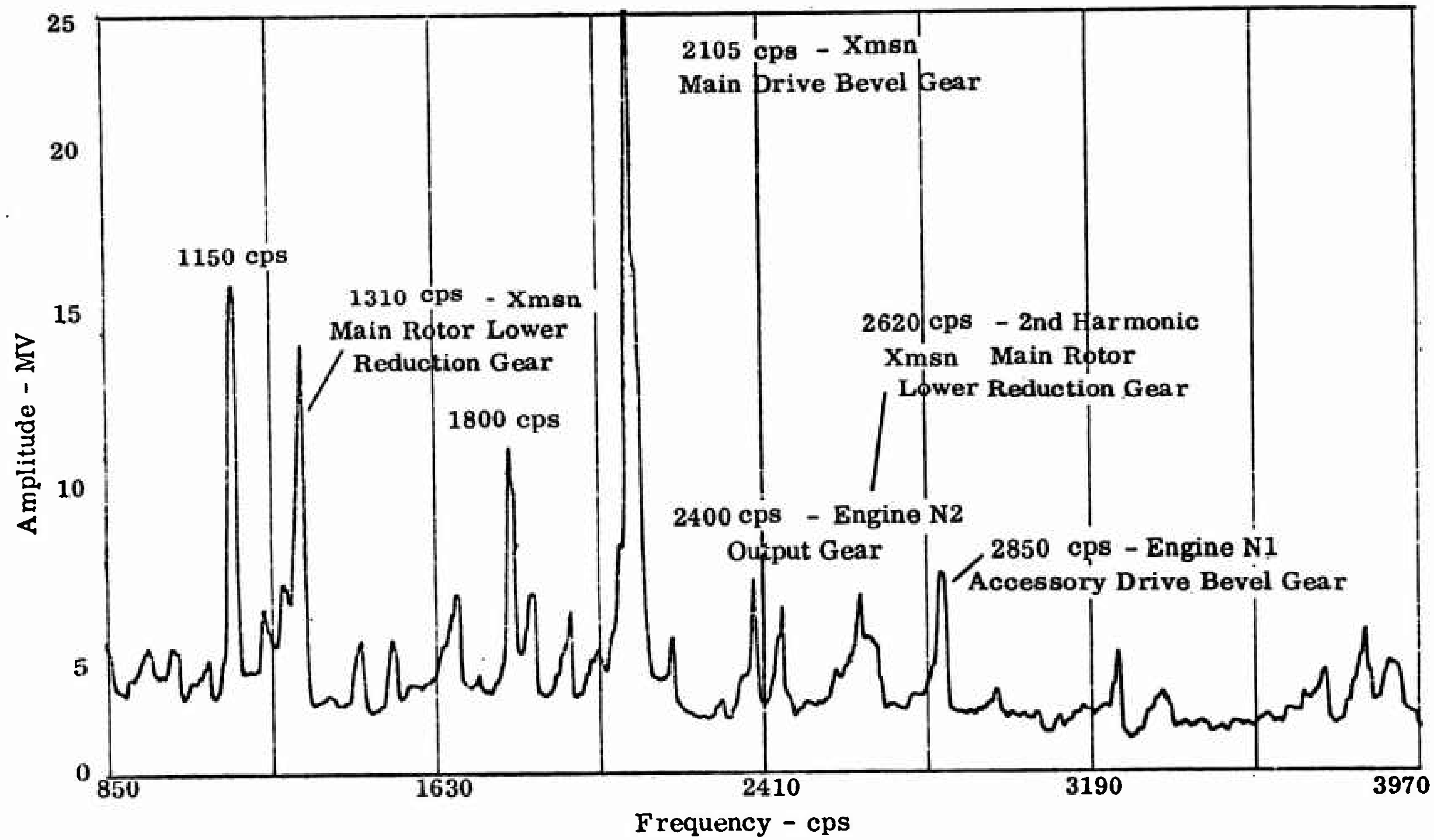

Figure 12. Amplitude vs. Frequency Spectrogram of Engine and Transmission Gear Signals (Transmission Microphone) - UH-1B Helicopter Serial Number 62-1925, Transmission Speed = 4362 RPM, Engine N1 Speed at 60%.

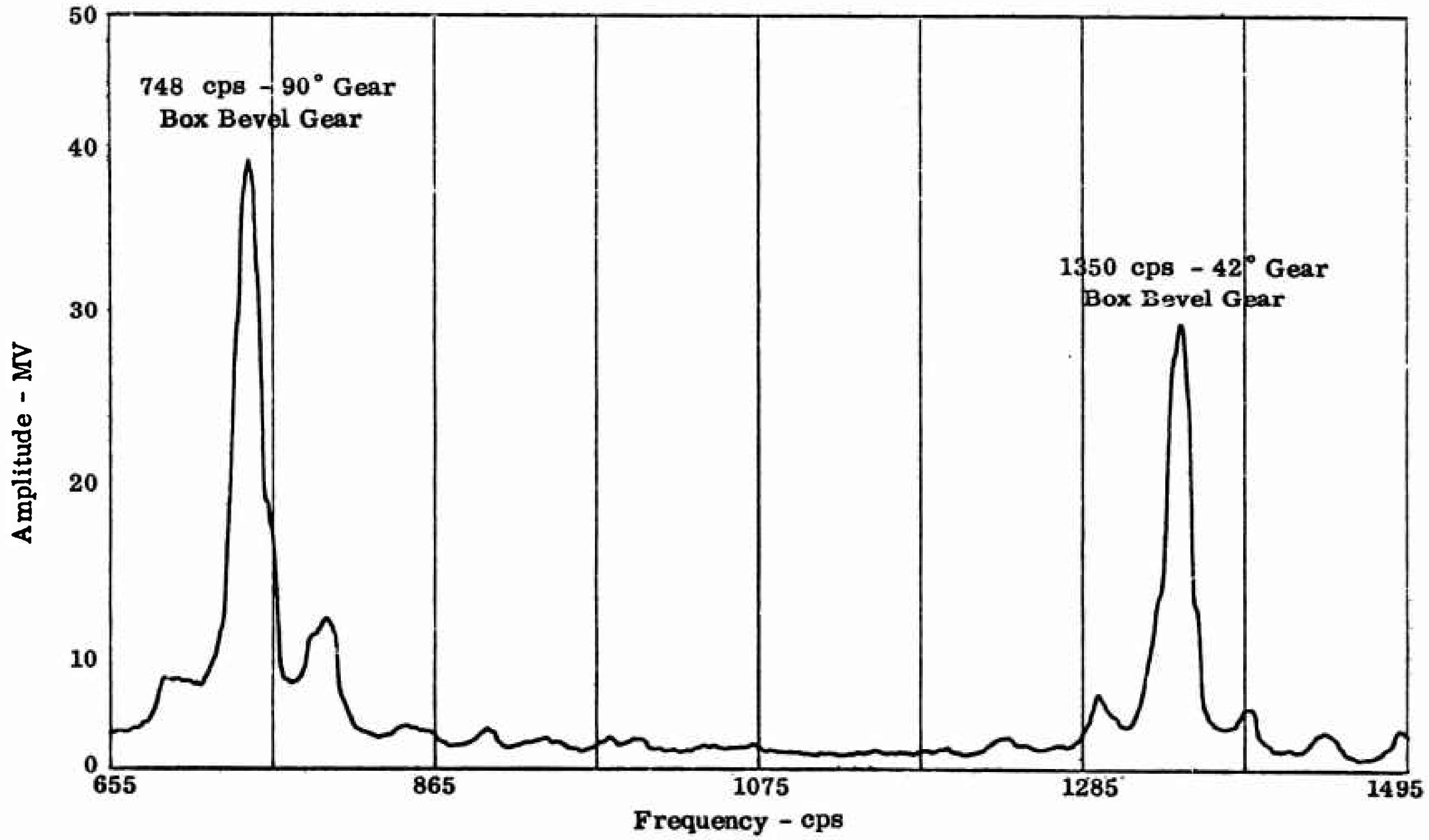

Figure 13. Amplitude vs. Frequency Spectrogram of Tail Rotor Drive 42° and 90° Gear Box Signals (Tail Rotor Microphone) - UH-1A Helicopter Serial Number 59-1709, Transmission Speed = 4600 RPM.

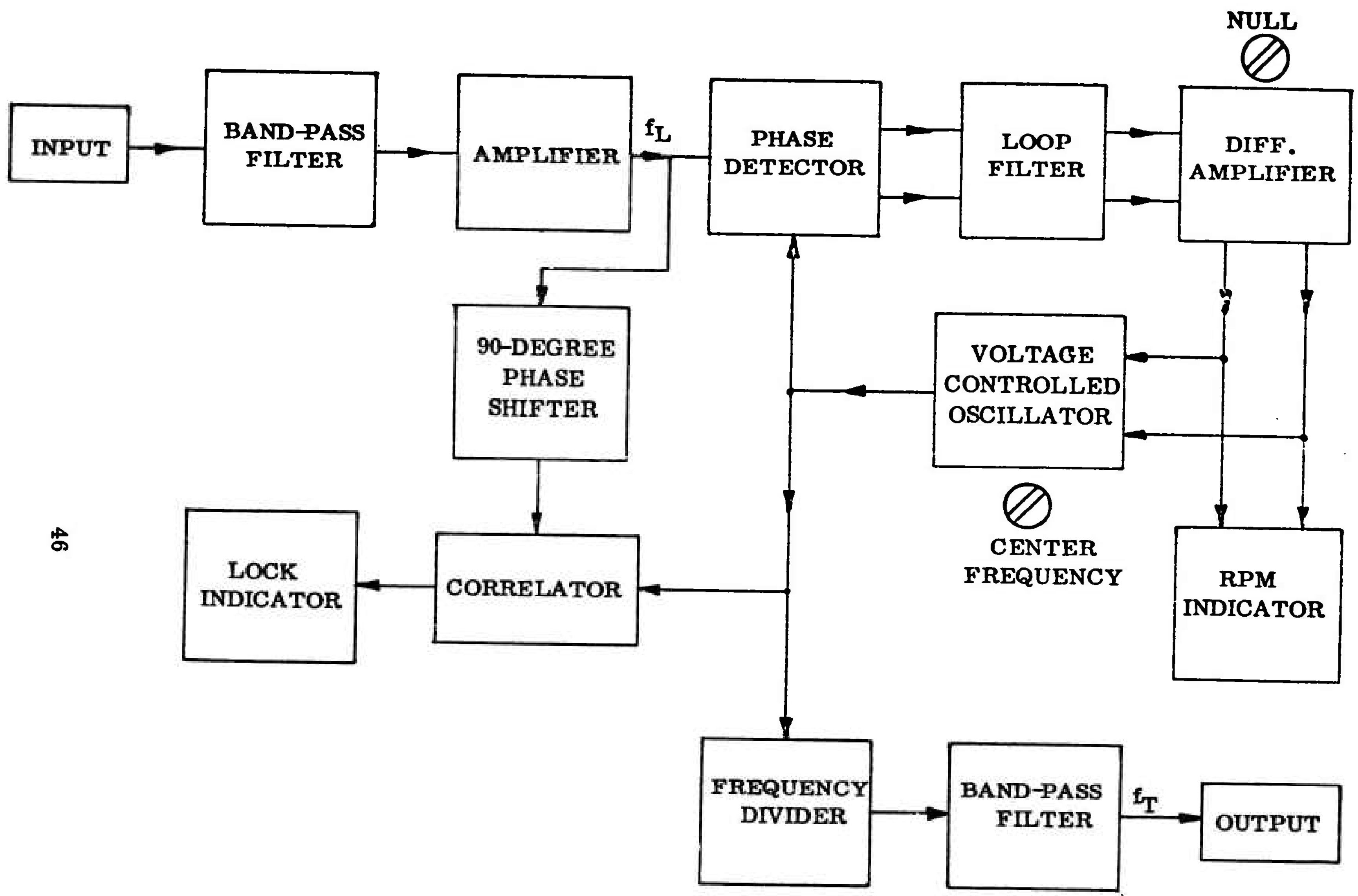

Figure 14. Block Diagram - Phase Locked Filter.

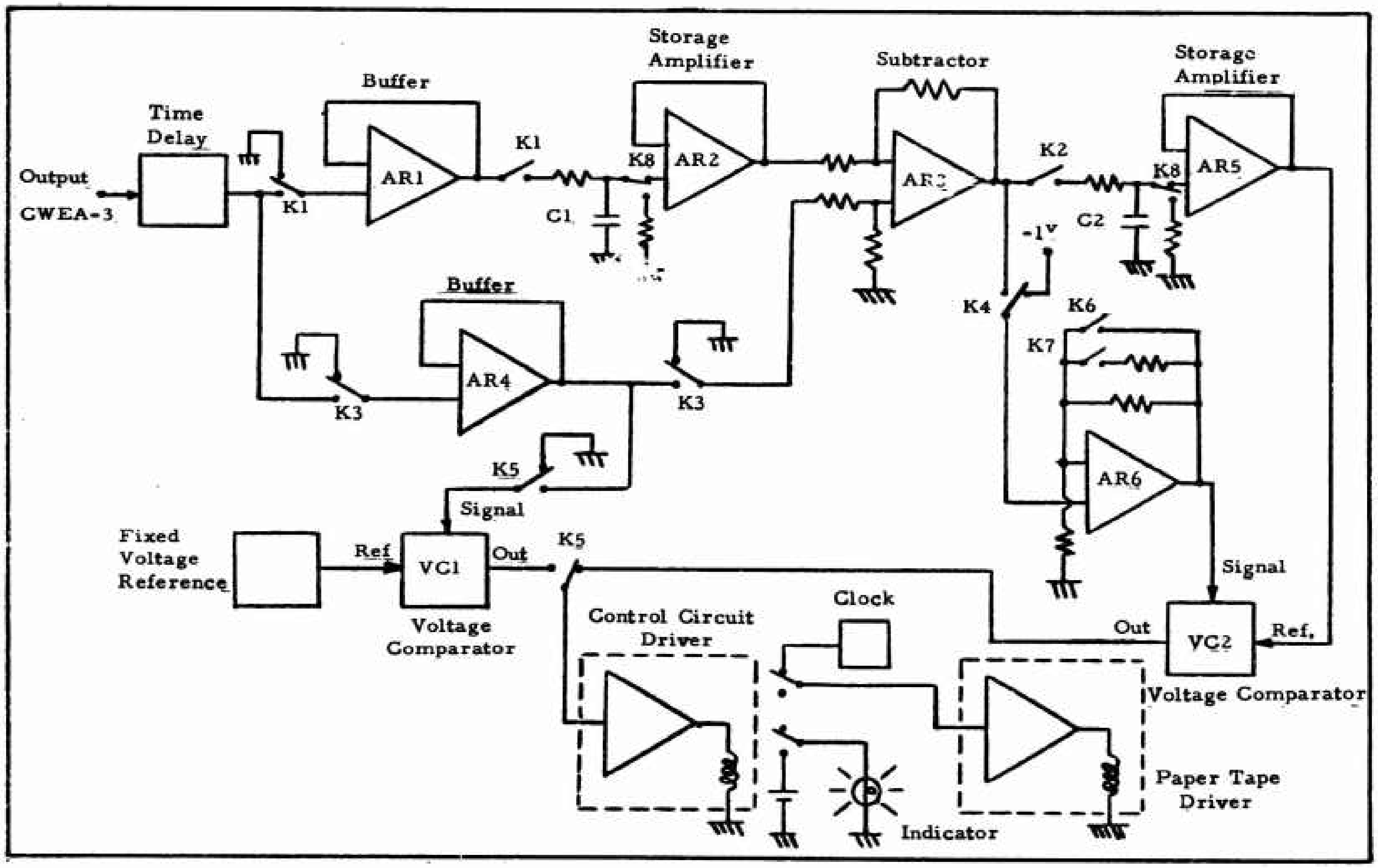

Figure 15. Automation Data Loop - CWEA-4 Sonic Analyzer.

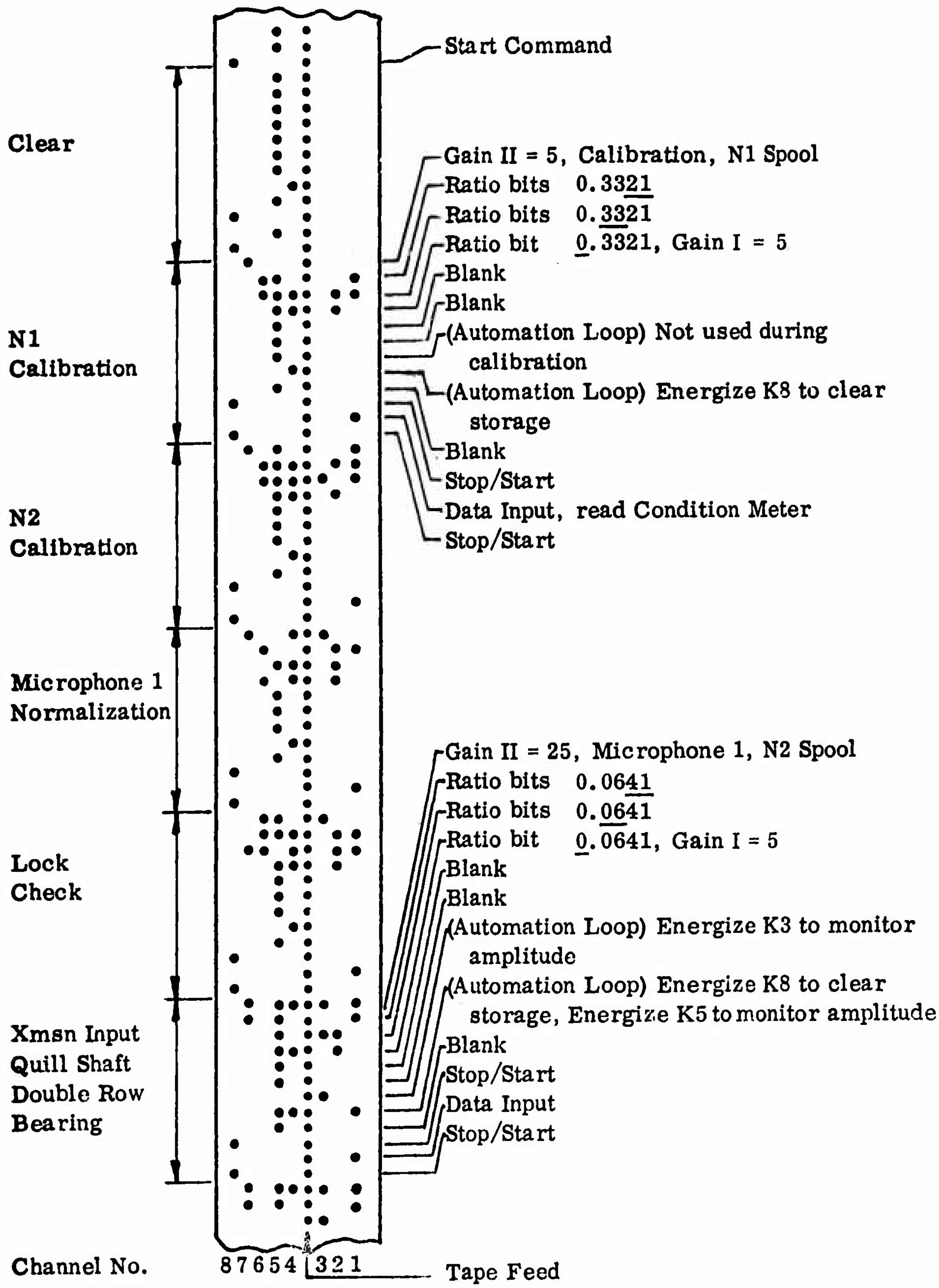

Figure 16. Sample Program Tape - CWEA-4 Sonic Analyzer.

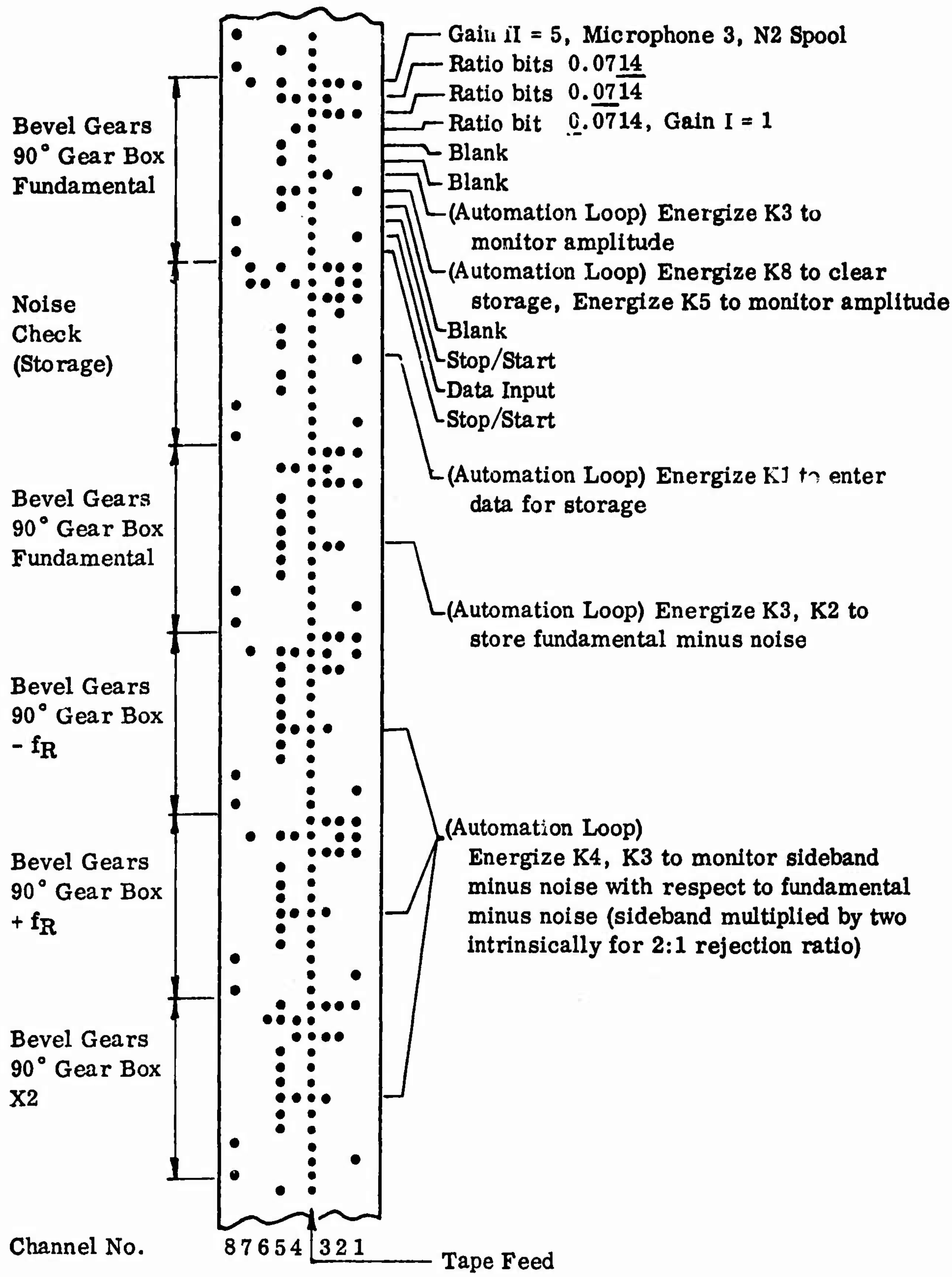

Figure 17. Sample Program Tape - CWEA-4 Sonic Analyzer.

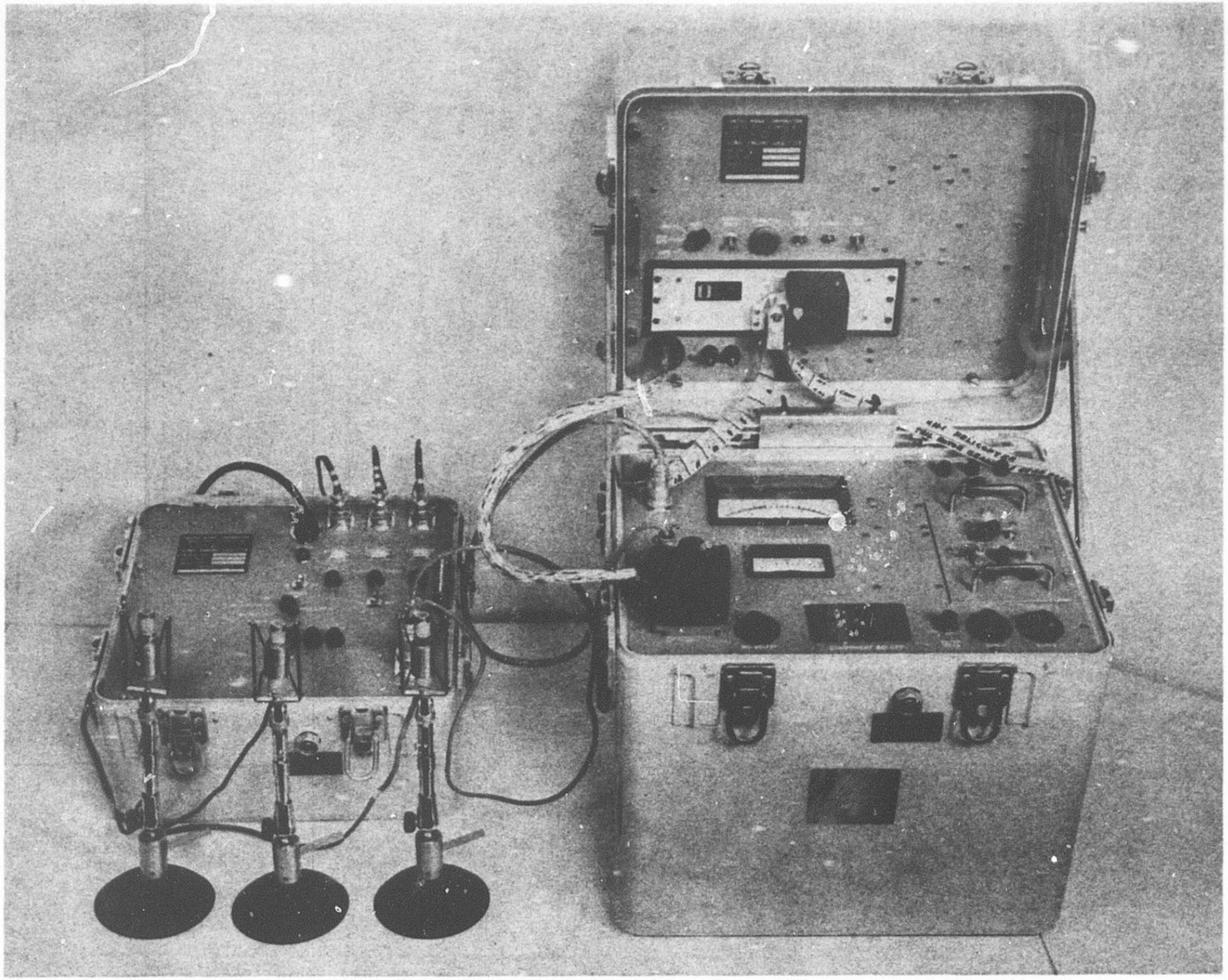

Figure 18. Model CWEA-4 Sonic Analyzer System with UH-1 Plug-In Module and Program Tape.

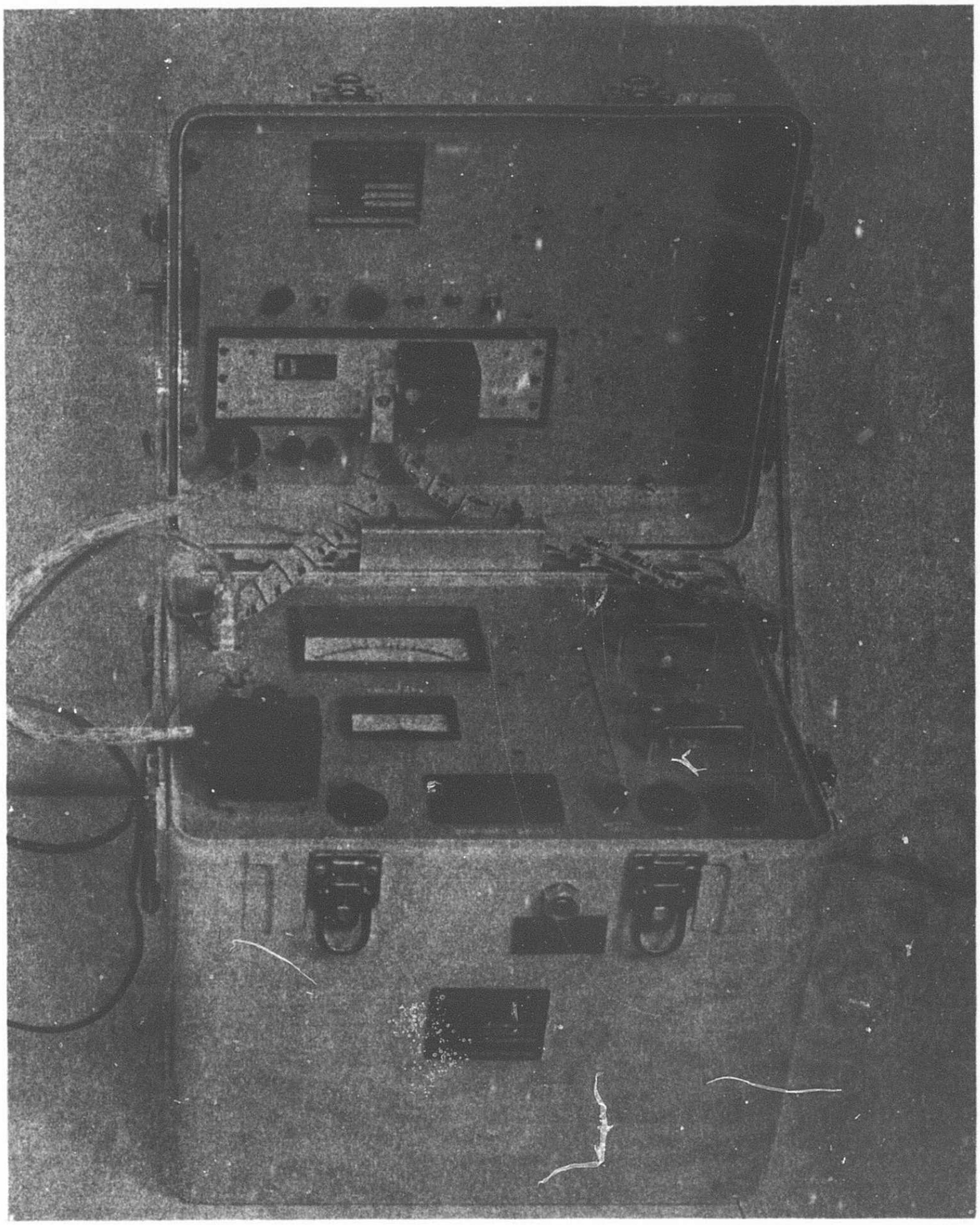

Figure 19. Model CWEA-4 Sonic Analyzer Panel - Close-Up.

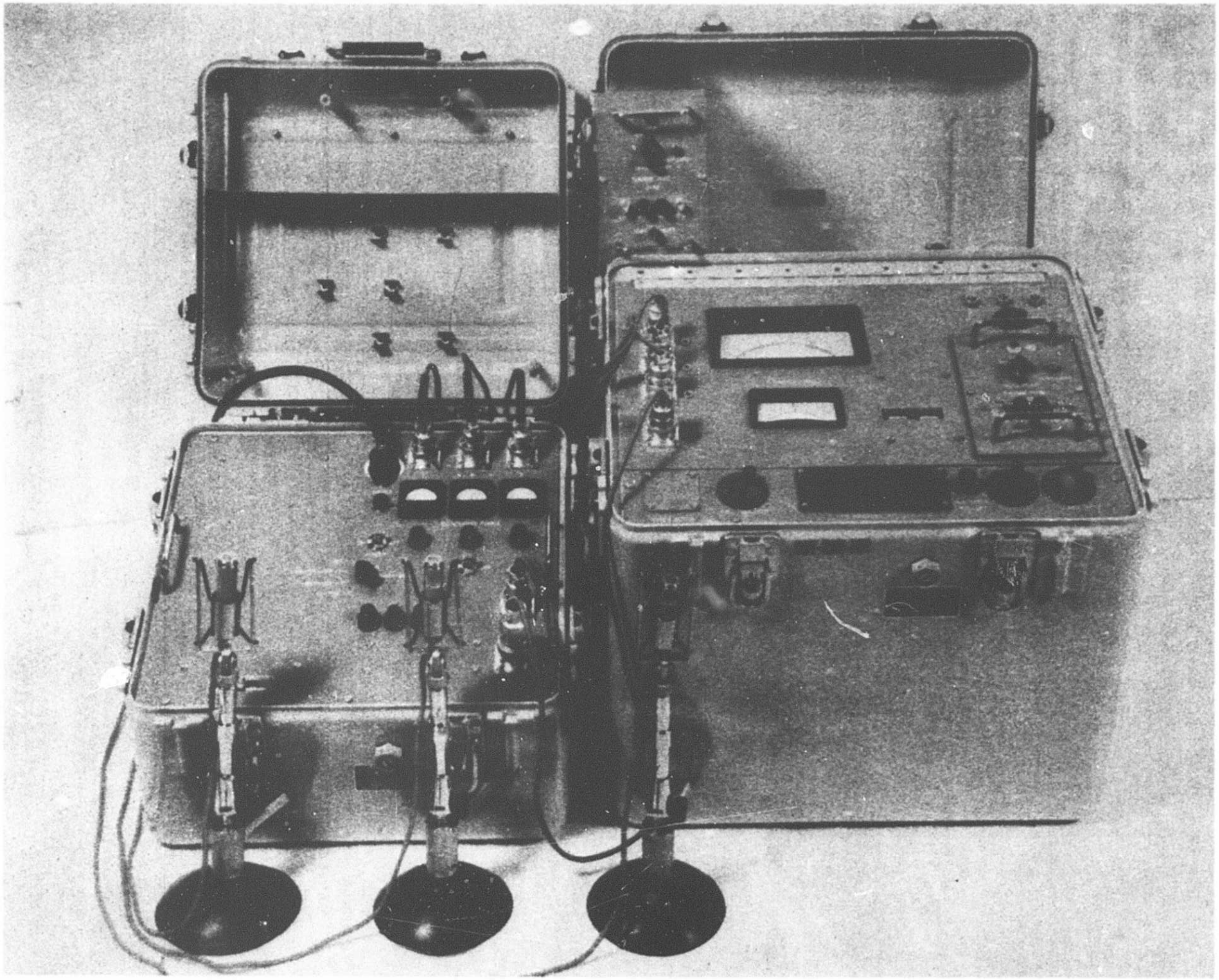

Figure 20. Model CWEA-3 Sonic Analyzer.

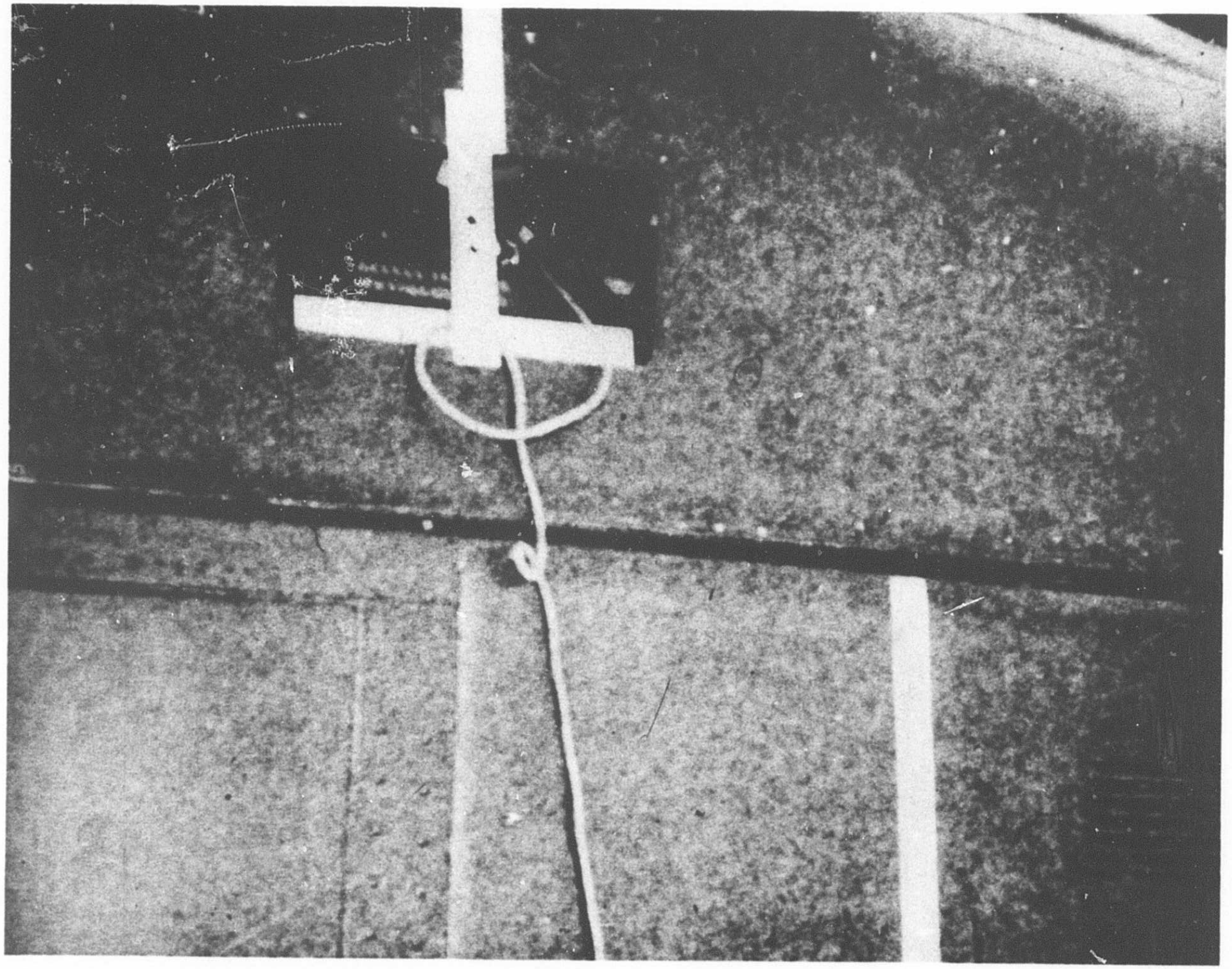

Figure 21. Typical Installation of Transmission Microphone on Models UH-1A, UH-1B, and UH-1C Helicopters.

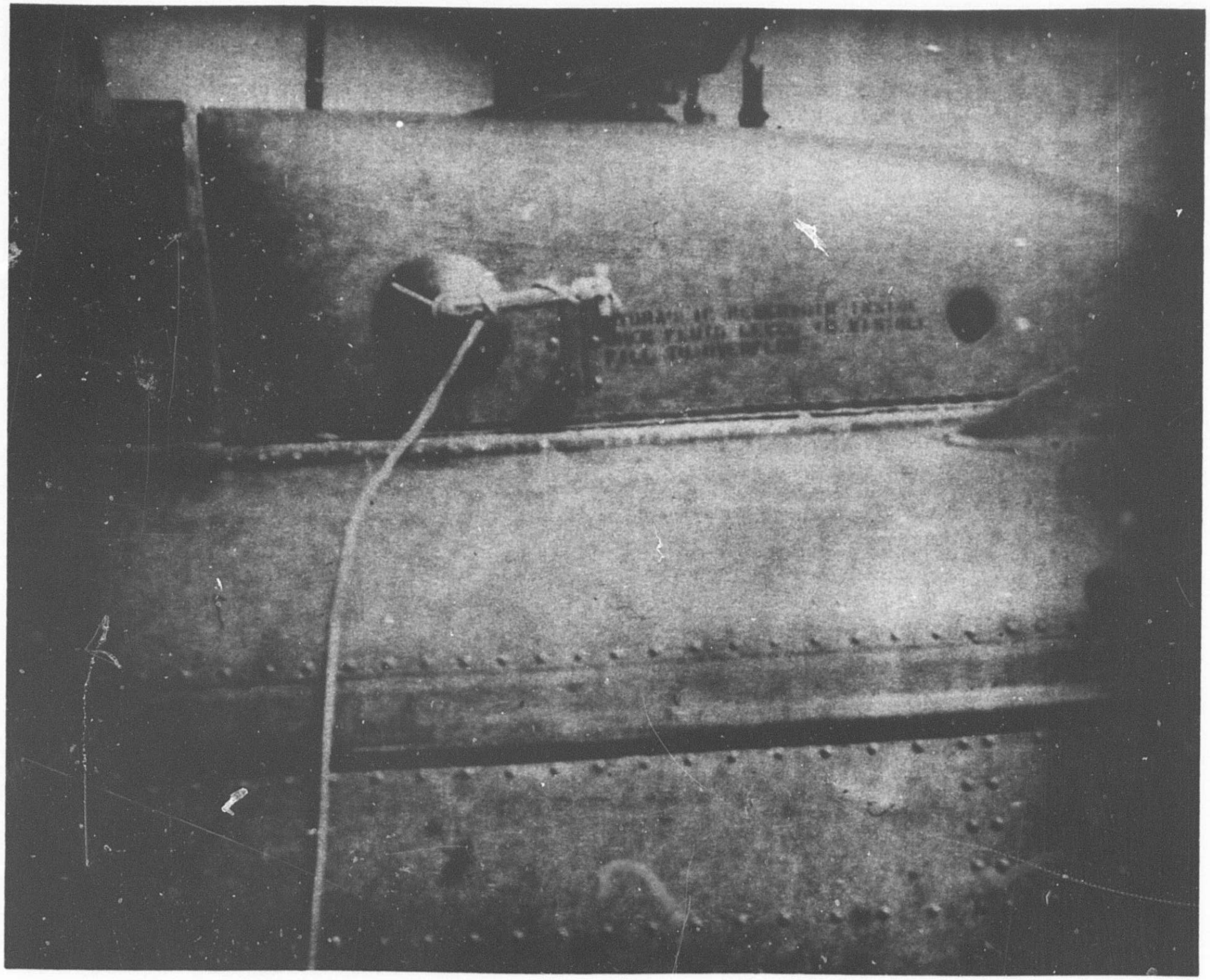

Figure 22. Typical Installation of Transmission Microphone on Model UH-1D Helicopter.

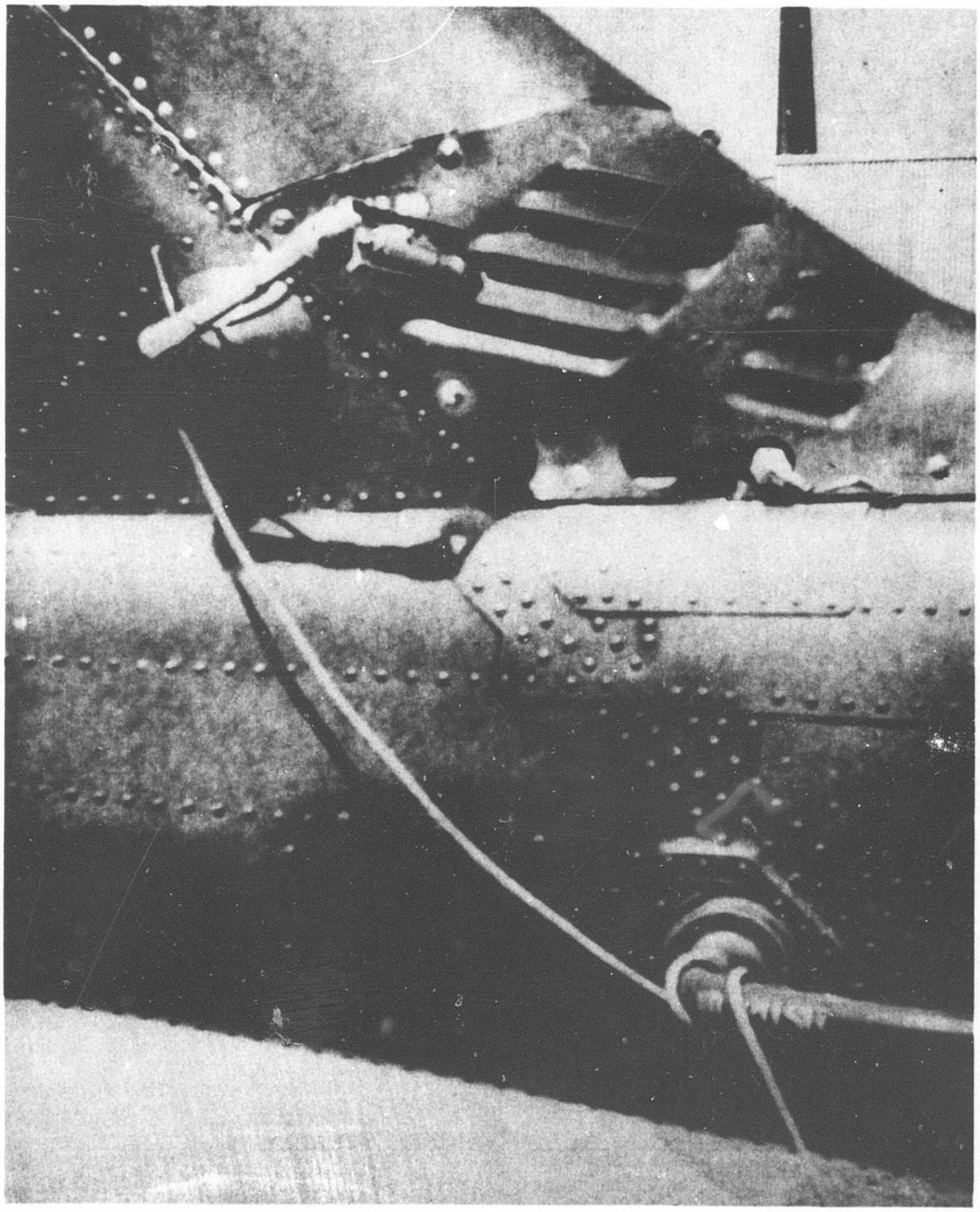

Figure 23. Typical Installation of Tail Rotor Microphone on Models UH-1A, UH-1B, UH-1C and UH-1D Helicopters.

Figure 24. Model CWEA-4 Sonic Analyzer in Operation at Fort Rucker, Alabama.

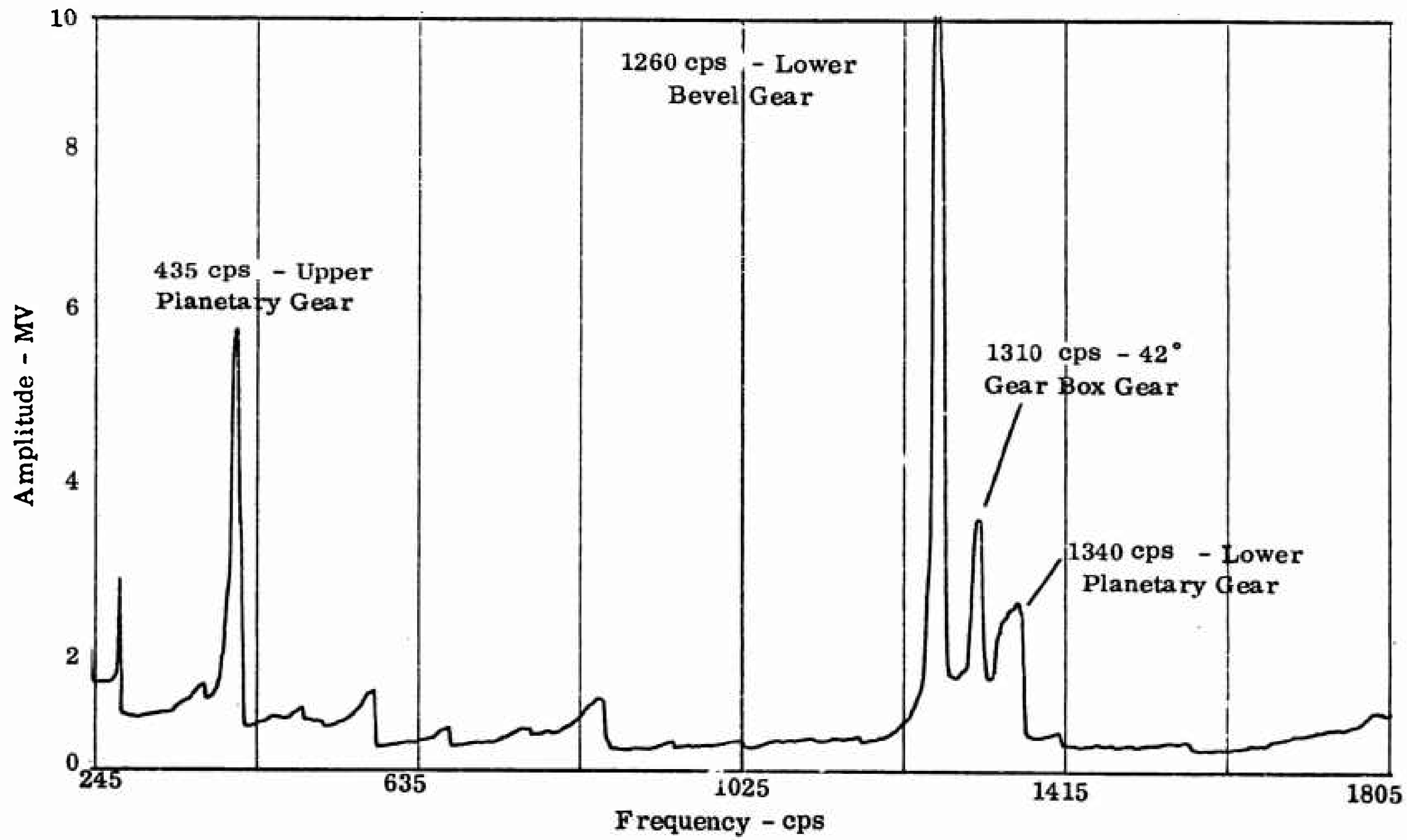

Figure 25. Amplitude vs. Frequency Spectrogram of Transmission Gears (Transmission Microphone) Showing High Amplitude Signal for Lower Bevel Drive Gears and Main Rotor Upper Planetary Gear - UH-1B Helicopter Serial Number 61-0730 Analyzed on 17 August 1967, Transmission Speed = 4470 RPM.

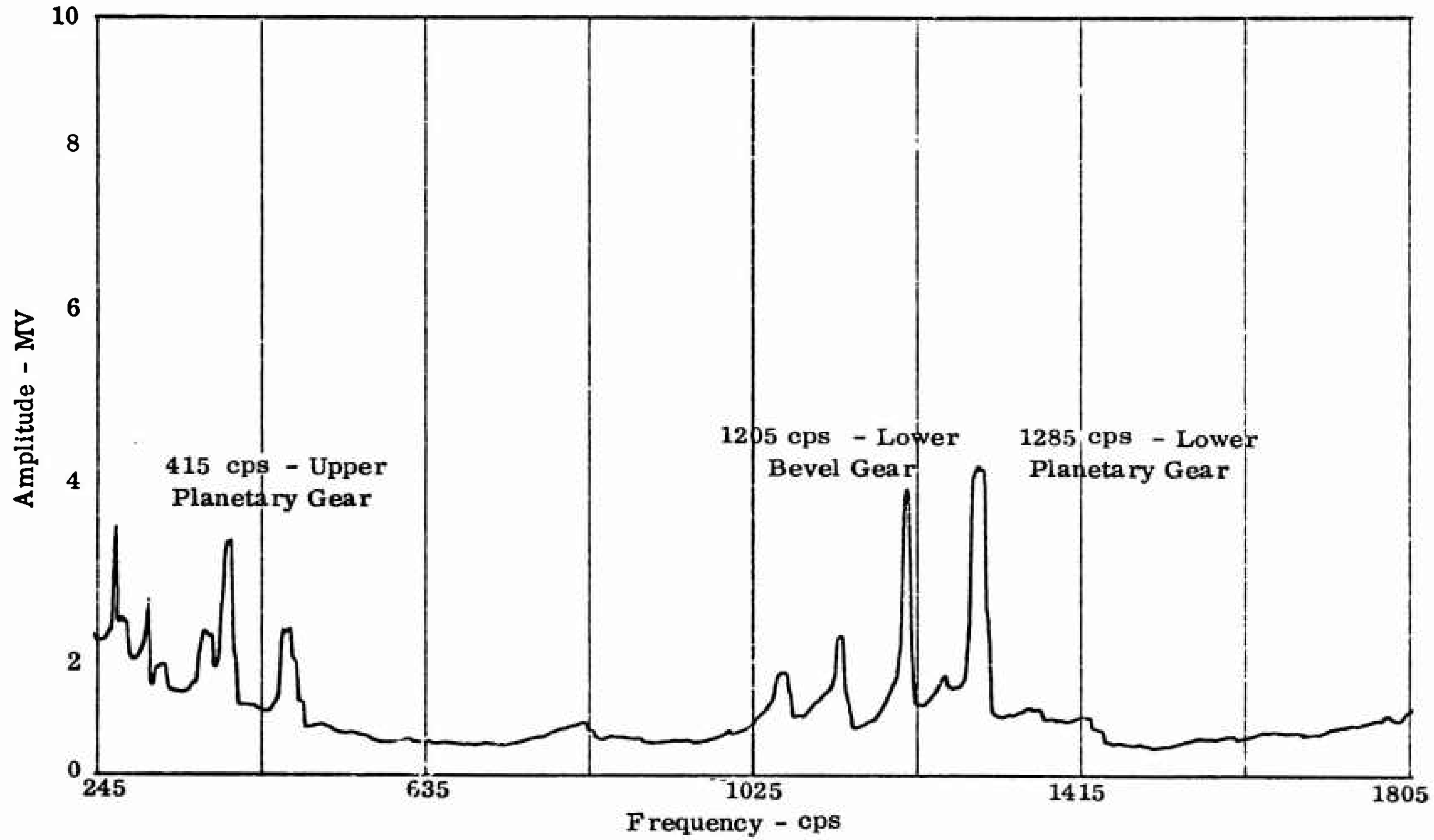

Figure 26. Amplitude vs. Frequency Spectrogram of Normal Transmission Gear Signals (Transmission Microphone) - UH-1B Helicopter Serial Number 61-0745 Analyzed on 25 July 1967, Transmission Speed = 4270 RPM.

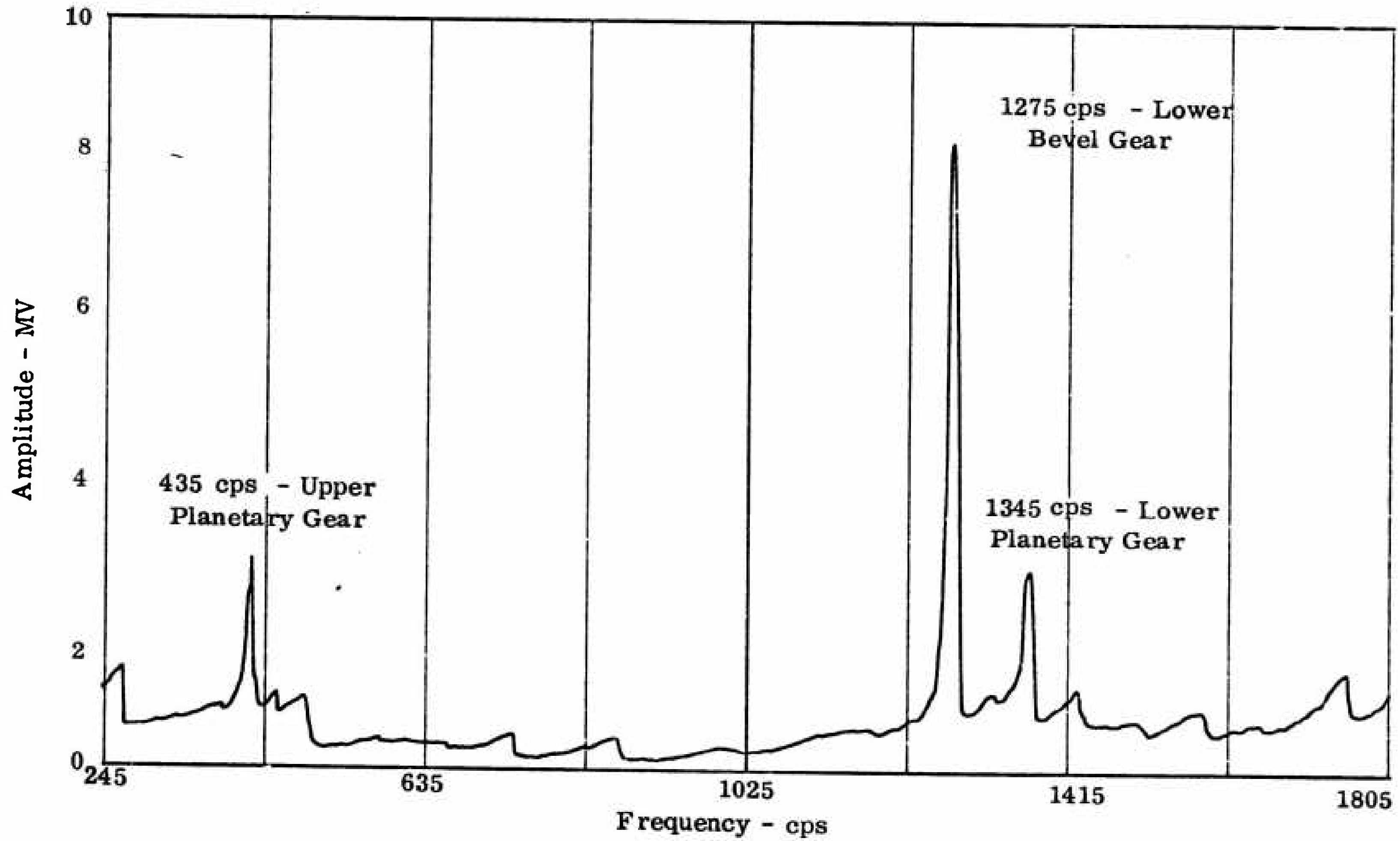

Figure 27. Amplitude vs. Frequency Spectrogram of Transmission Gears (Transmission Microphone) Showing High Amplitude Signal for Lower Bevel Drive Gears - UH-1B Helicopter Serial Number 62-1964 Analyzed on 30 August 1967, Transmission Speed = 4490 RPM.

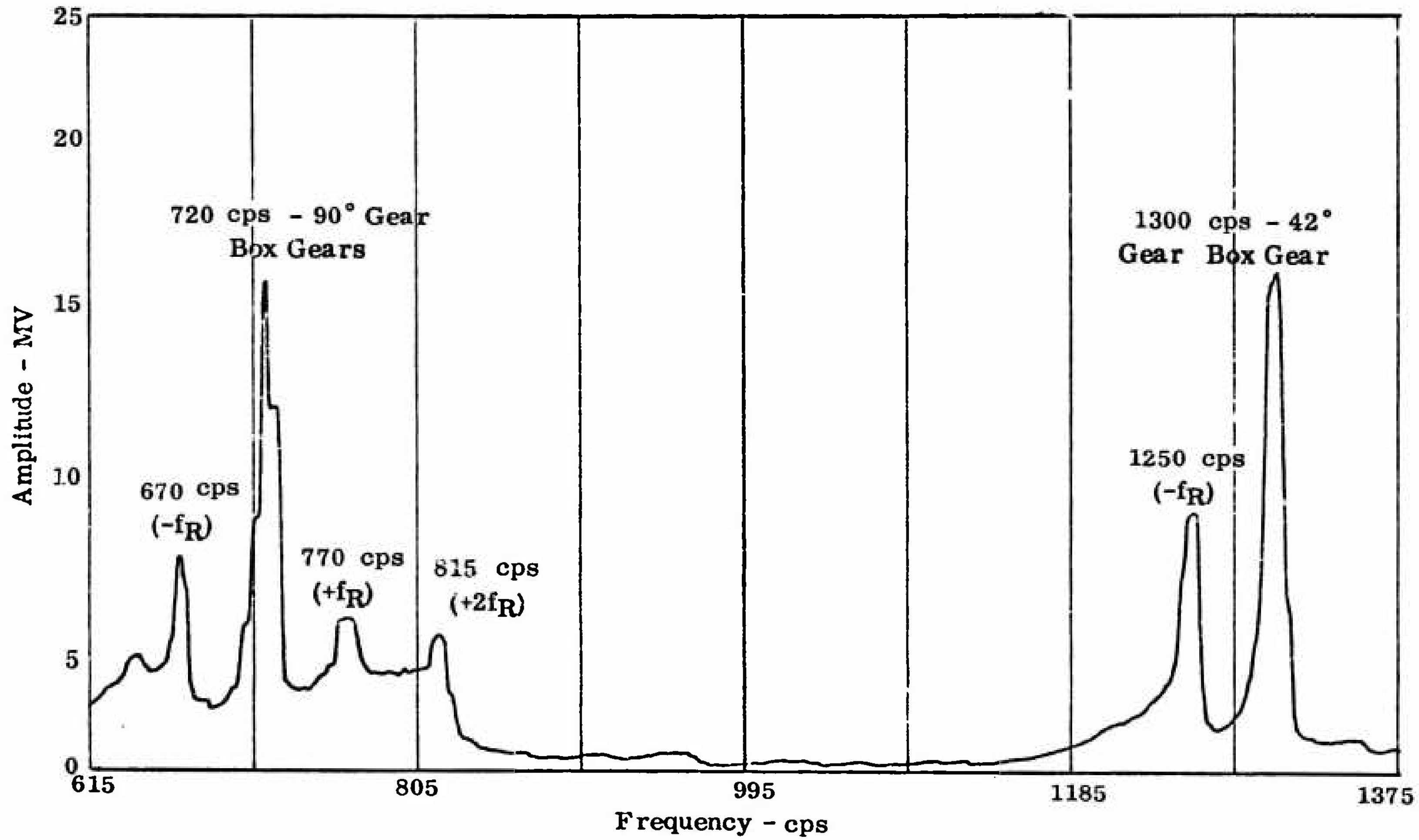

Figure 28. Amplitude vs. Frequency Spectrogram of Tail Rotor Drive Gear Box Gears (Tail Rotor Microphone) Showing Relatively High Amplitude Sideband Signals for Both 42° and 90° Gear Box Gears - UH-1B Helicopter Serial Number 61-0745 Analyzed on 30 August 1967, Transmission Speed = 4430 RPM.

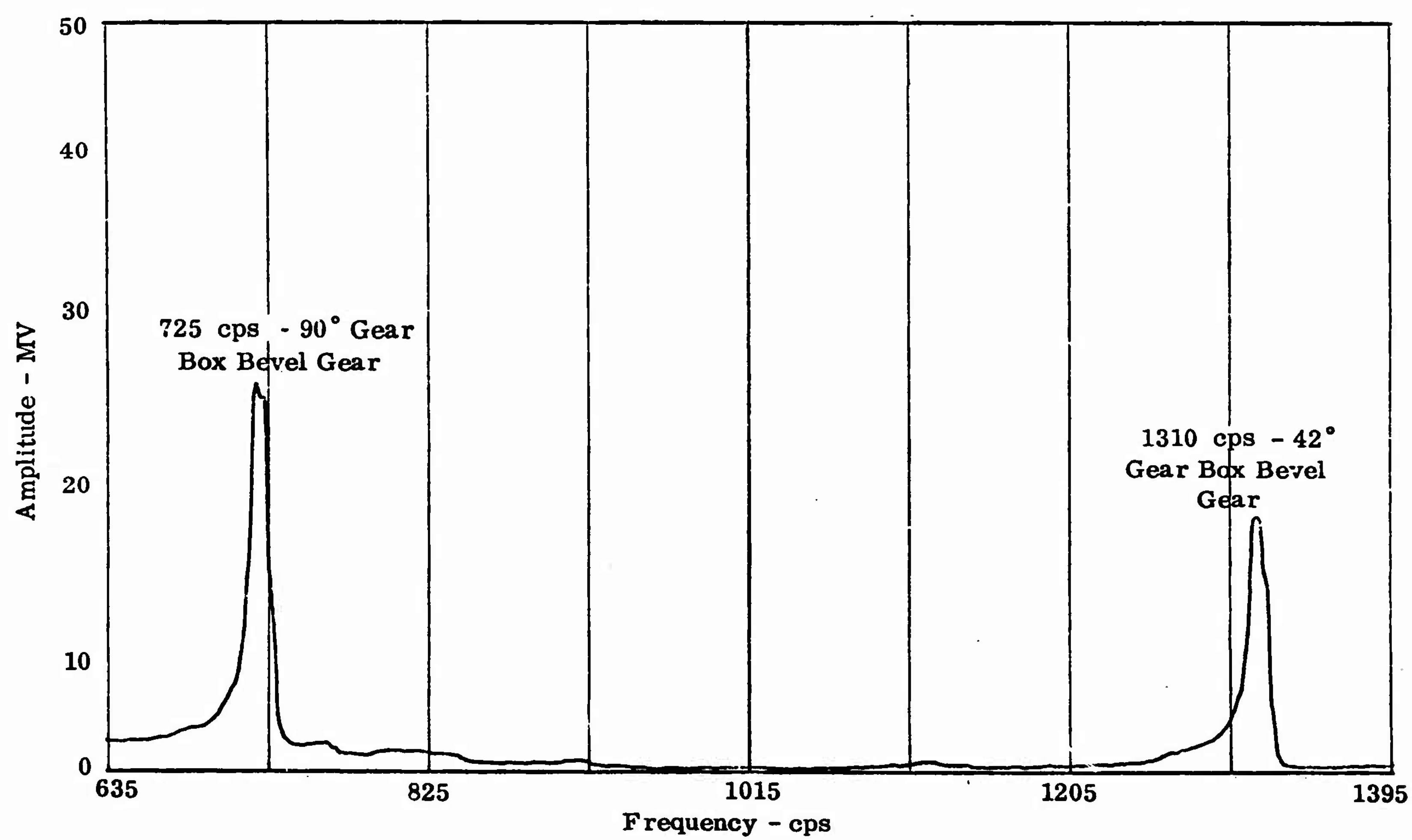

Figure 29. Amplitude vs. Frequency Spectrogram of Normal 42° and 90° Tail Rotor Gear Box Gear Signals (Tail Rotor Microphone) - UH-1B Helicopter Serial Number 61-0730 Analyzed on 17 August 1967, Transmission Speed = 4470 RPM.

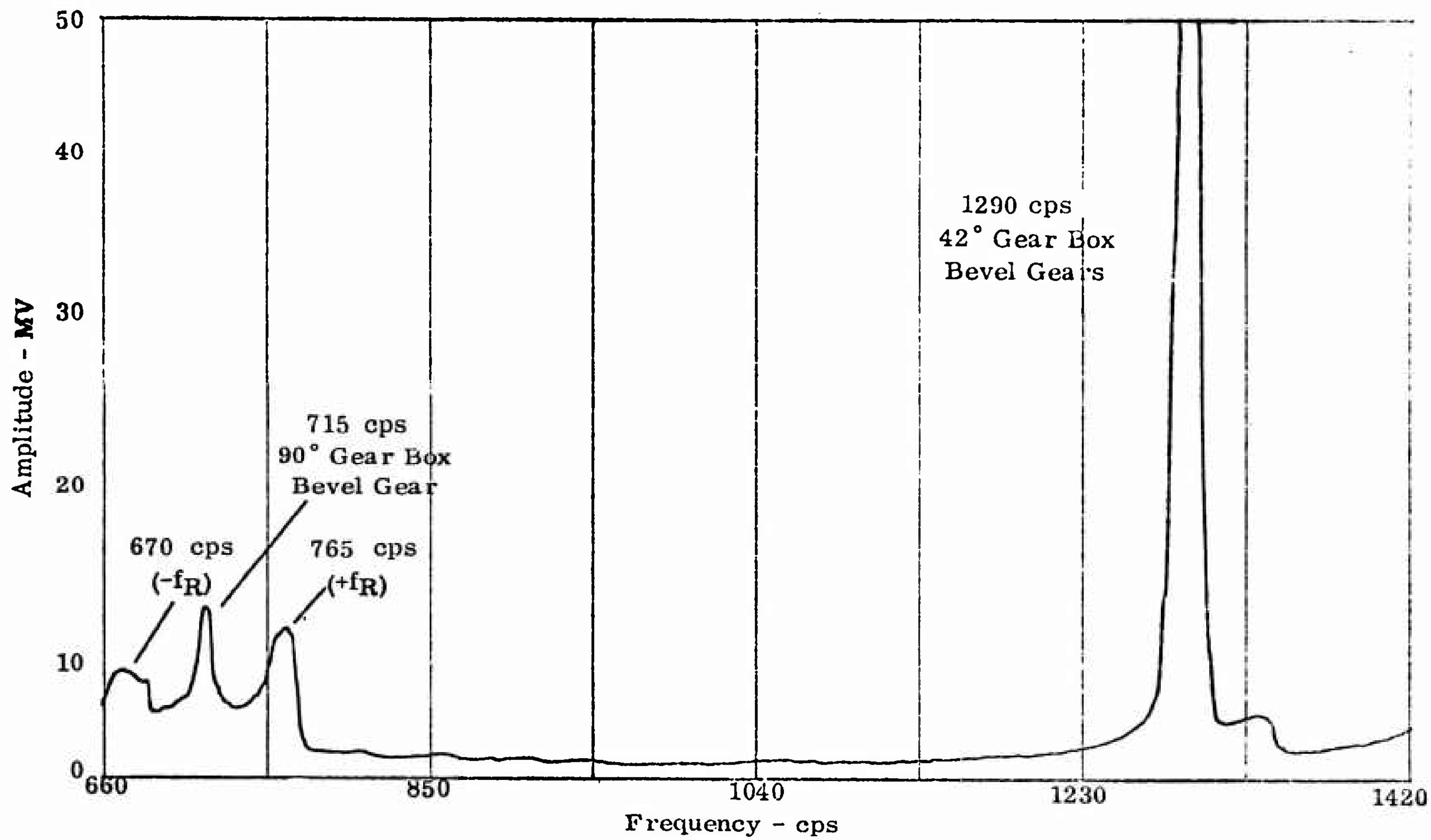

Figure 30. Amplitude vs. Frequency Spectrogram of 42° and 90° Tail Rotor Gear Box Gears (Tail Rotor Microphone) Showing Relatively High Amplitude Sideband Signals for 90° Gear Box Gears - UH-1B Helicopter Serial Number 61-0730 Analyzed on 5 September 1967, Transmission Speed = 4400 RPM.

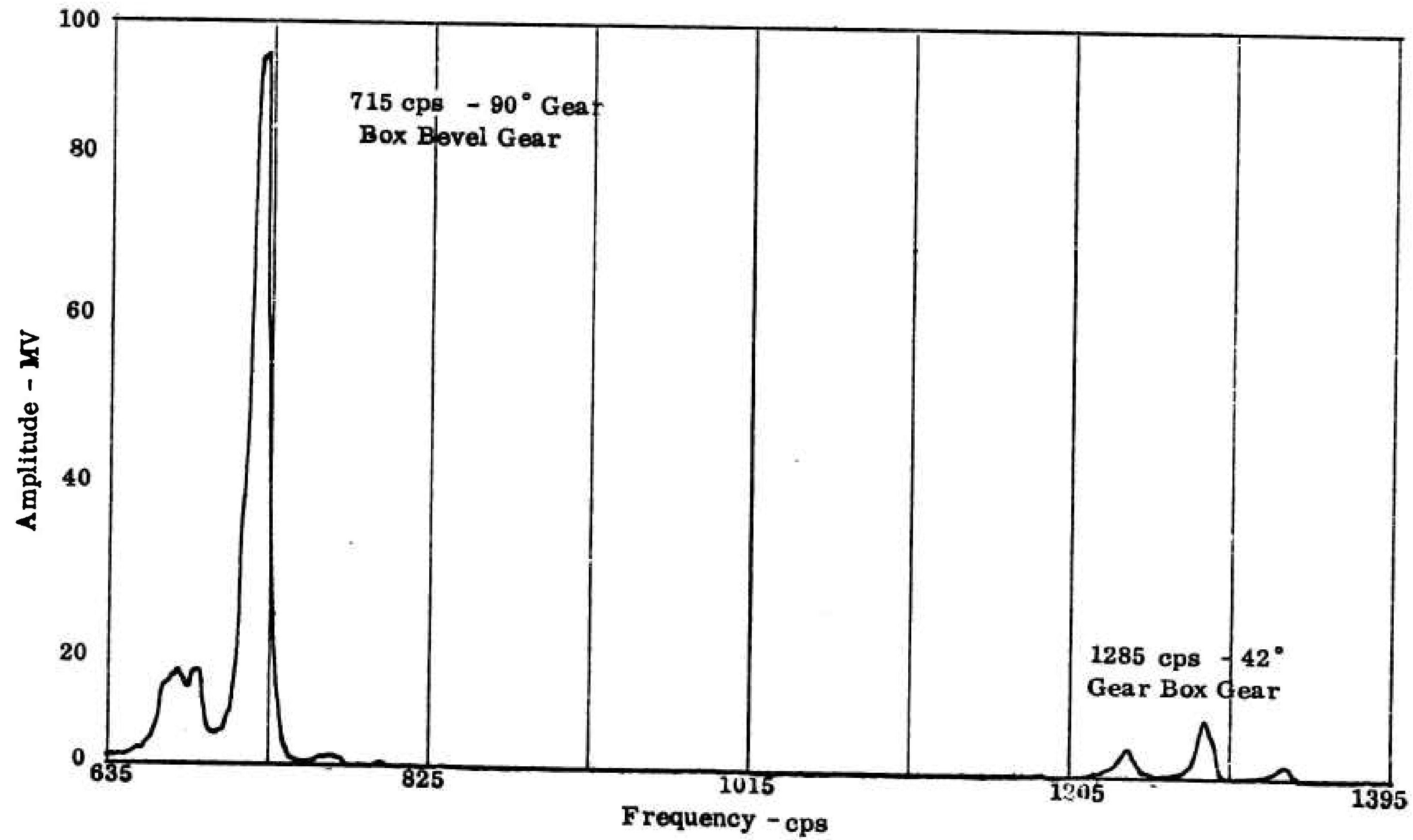

Figure 31. Amplitude vs. Frequency Spectrogram of Tail Rotor Drive Gear Box Gears (Tail Rotor Microphone) Showing Relatively High Amplitude Signal for 90° Gear Box Gears - UH-1B Helicopter Serial Number 61-0725 Analyzed on 18 July 1967, Transmission Speed = 4375 RPM.

TABLE I
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
GAS PRODUCER GROUP (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Component	Stage	No. Blades	Frequency (cps)
Compressor Rotor	1	26	6539
	2	28	7042
	3	34	8551
	4	36	9054
	5	38	9557
Centrifugal Impeller	1	36	9054
Turbine Rotor	1	80	20120

TABLE II
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
POWER TURBINE GROUP (N_2)
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Component	Stage	No. Blades	Frequency (cps)
Turbine Rotor	2	62	14967

TABLE III
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
ACCESSORY DRIVE SECTION - GAS PRODUCER DRIVEN (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Component	Ref*	Frequency (cps)
Outer Drive Bevel Gear	(1)	8551
Outer Driven Bevel Gear	(2)	8551
Inner Drive Bevel Gear	(3)	2850
Inner Driven Bevel and Starter-Generator Drive Gear	(4a)	2850
Inner Drive Spur Gear	(4b)	1710
N_1 Tachometer Generator Idler Gear	(5)	1710
N_1 Tachometer Generator Idler Gear	(6)	1596
N_1 Tachometer Generator Drive Gear	(7)	1596
Oil Pump Drive and Fuel Control Idler Gear	(8)	1710
Fuel Control Idler Gear	(9)	1629
Fuel Control Drive Gear	(10)	1629
Accessory Idler Gear	(29)	999
Accessory Drive Gear	(30)	999
Fuel Assembly Gears		
Drive Gear	(22)	1111
Flyweight Drive Gear	(23)	1111
Accessory Drive Gear	(24)	1111
Accessory Gear	(26)	555
Pump Gear	(25)	370
Oil Pump (Gear Type)	(27)	407
Oil Pump (Vane Type)	**	163

* Refer to Figure 1 for location of these gears.
** Vane type option not shown.

TABLE IV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
OUTPUT REDUCTION GEARING AND ACCESSORY SECTION
POWER TURBINE DRIVEN (N_2)
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Component	Ref*	Frequency (cps)
Drive Spur Gear	(1)	7725
Planet Gear	(2)	7725
Output Ring Gear	(3)	7725
Accessory Drive Bevel Gear	(4)	2625
Accessory Driven Bevel Gear	(5)	2625
Accessory Drive Gear	(6)	1200
Accessory Driven Gear and N_2 Tachometer Drive	(7)	1200
Idler Gear	(8)	1356
N_2 Overspeed Governor Drive Gear	(9)	1356

* Refer to Figure 2 for location of these gears.

TABLE V
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
PLANETARY SUN GEAR SUPPORT BEARING*
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	241
f_T	97
f_B	599
f_B'	1198
$3f_B'$	3593
f_1	1441
f_2	973

* Bearing Dimensions (Lycoming P/N 1-300-009-01, MRC P/N 209-S-300)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.0774"
Outer Race I.D. (d_2)	3.0774"
No. of Balls (m)	10

TABLE VI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
NO. 1 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	103
f_B	675
f_B'	1349
$3f_B'$	4047
f_1	1930
f_2	1340

* Bearing Dimensions (Lycoming P/N 1-300-015-02)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2720"
Outer Race I.D. (d_2)	3.2720"
No. of Balls (m)	13

TABLE VI-a
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
OPTIONAL NO. 1 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	103
f_B	671
f_B'	1341
$3f_B'$	4024
f_1	2081
f_2	1440

* Bearing Dimensions (Lycoming P/N 1-300-015-04, Fafnir P/N MM210VM2SMBRE7730)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2559"
Outer Race I.D. (d_2)	3.2599"
No. of Balls (m)	14

TABLE VII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
NO. 2 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	110
f_B	998
f_B'	1995
$3f_B'$	5985
f_1	2829
f_2	2201

* Bearing Dimensions (Lycoming P/N 1-300-013-04, Rollway P/N HU1011EAR5706)

Roller Diameter (d_B)	0.3543"
Inner Race O.D. (d_1)	2.4990"
Outer Race I.D. (d_2)	3.2110"
No. of Rollers (m)	20

TABLE VIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
NO. 3 MAIN ENGINE BEARING*
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	241
f_T	106
f_B	957
f_B'	1915
$3f_B'$	5745
f_1	2715
f_2	2113

* Bearing Dimensions (Lycoming P/N 1-300-013-04, Rollway P/N HU1011EAR5706)

Roller Diameter (d_B)	0.3543"
Inner Race O.D. (d_1)	2.4990"
Outer Race I.D. (d_2)	3.2110"
No. of Rollers (m)	20

TABLE IX
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
NO. 4 MAIN ENGINE BEARING*
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	241
f_T	99
f_B	647
$f_B{}'$	1295
$3f_B{}'$	3884
f_1	1852
f_2	1286

* Bearing Dimensions (Lycoming P/N 1-300-015-02, New Departure P/N V3210RS5470C09)

Roller Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2720"
Outer Race I.D. (d_2)	3.2720"
No. of Balls (m)	13

TABLE X
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
GEAR TRAIN BEARINGS - GAS PRODUCER DRIVEN (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing	Lycoming P/N		Frequency (cps)			
Description	and Vendor	Ref*	f_1	f_2	$f_B{}'$	$3f_B{}'$
Outer Driven Bevel	1-300-001-01 (MRC)	(11)	799	559	743	2230
Gear	2-300-023-02 (ND)	(11)	798	559	745	2236
Inner Drive Bevel Gear	1-300-006-01 (MRC)	(12)	1068	832	1076	3229
Inner Drive Bevel	1-300-002-01 (MRC)	(13)	732	490	657	1972
Gear	1-300-002-02 (Fafnir)	(13)	732	490	657	1972
Inner Driven Bevel Gear	1-300-012-01 (MRC)	(14)	357	213	262	787
Inner Driven Bevel	1-300-006-01 (MRC)	(15)	561	437	565	1695
Gear	1-300-006-02 (SKF)	(15)	560	437	567	1702
N_1 Tachometer Gen Idler Gear	1-300-003-01 (MRC)	(16)	338	232	298	895
N_1 Tachometer Gen Gear	1-300-003-01 (MRC)	(18)	249	171	220	660
Oil Pump Drive & Fuel Control Idler Gear	1-300-003-01 (MRC)	(19)	241	166	213	639
Oil Pump Drive &	1-300-004-01 (MRC)	(20)	262	186	234	703
Fuel Control Idler Gear	1-300-004-02 (SKF)	(20)	262	186	234	703
Fuel Control Drive	1-300-005-01 (MRC)	(21)	237	170	217	651
& Accessory Idler Gear	1-300-005-02 (SKF)	(21)	275	206	255	765
Accessory Drive Gear	1-300-005-01 (MRC)	(28)	237	170	217	651
Accessory Drive Gear	1-300-003-01 (MRC)	(31)	219	151	194	581

* Refer to Figure 1 for location of these bearings.

TABLE XI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL T53-L-1A ENGINE
GEAR TRAIN BEARINGS - POWER TURBINE DRIVEN (N_2)
(N_2 = 74.5% OF 19442 RPM = 14484 RPM)

Bearing Description	Lycoming P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Drive Sun Gear	1-300-009-01 (MRC)	(17)	1441	973	1197	3593
Planet Gear	1-300-014-01 (NH)	(10)	1345	862	960	2880
Driven Ring Gear -	1-300-011-01 (MRC)	(12)	993	807	715	2146
Output Shaft	1-300-011-02 (Rollway)	(12)	903	747	790	2370
	1-300-011-03 (SKF)	(12)	993	807	721	2162
Driven Ring Gear - Output Shaft	1-300-008-01 (MRC)	(11)	671	529	627	1882
Driven Bevel Gear - Accessory	1-300-003-01 (MRC)	(13)	444	306	392	1178
Drive Spur Gear	1-300-003-01 (MRC)	(14)	444	306	392	1178
N_2 Tachometer Gen	1-300-003-01 (MRC)	(15)	309	213	273	819
Gear and Idler Gear	1-300-003-02 (Fafnir)	(15)	309	213	273	819
N_2 Overspeed Governor	1-300-003-01 (MRC)	(16)	268	184	237	710

* Refer to Figure 2 for location of these bearings.

TABLE XII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
GAS PRODUCER GROUP (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Component	Stage	No. Blades	Frequency (cps)
Compressor Rotor	1	26	6539
	2	28	7042
	3	34	8551
	4	36	9054
	5	38	9557
Centrifugal Impeller	1	36	9054
Turbine Rotor	1	66	16599

TABLE XIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
POWER TURBINE GROUP (N_2)
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Component	Stage	No. Blades	Frequency (cps)
Turbine Rotor	2	62	14905

TABLE XIV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
ACCESSORY DRIVE SECTION - GAS PRODUCER DRIVEN (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Component	Ref*	Frequency (cps)
Outer Drive Bevel Gear	(1)	8551
Outer Driven Bevel Gear	(2)	8551
Inner Drive Bevel Gear	(3)	2850
Inner Driven Bevel and Starter - Generator Drive Gear	(4a)	2850
Inner Drive Spur Gear	(4b)	1710
N_1 Tachometer Generator Idler Gear	(5)	1710
N_1 Tachometer Generator Idler Gear	(6)	1596
N_1 Tachometer Generator Drive Gear	(7)	1596
Oil Pump Drive and Fuel Control Idler Gear	(8)	1710
Fuel Control Idler Gear	(9)	1751
Fuel Control Drive Gear	(10)	1751
Fuel Assembly Gears		
Drive Gear	(22)	1282
Flyweight Drive Gear	(23)	1282
Accessory Drive Gear	(24)	1282
Accessory Gear	(26)	641
Pump Gears	(25)	427
Oil Pump (Gear Type)	(27)	407
Oil Pump (Vane Type)	**	163

* Refer to Figure 3 for location of these gears.
** Vane type option not shown.

TABLE XV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
OUTPUT REDUCTION GEARING AND ACCESSORY SECTION
POWER TURBINE DRIVEN (N_2)
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Component	Ref*	Frequency (cps)
Drive Sun Gear	(1)	5048
Input Planet Gear	(2)	5048
Output Planet Gear	(3)	2475
Driven Sun Gear (Engine Output)	(4)	2475
Accessory Outer Drive Gear	(5)	2376
Accessory Outer Driven Gear	(6)	2376
Outer Drive Bevel Gear	(7)	955
Outer Driven Bevel Gear	(8)	955
Inner Drive Bevel Gear	(9)	1005
Inner Driven Bevel Gear and N_2 Tachometer Generator Drive	(10)	1005
Drive Spur Gear	(11)	1484
Idler Spur Gear	(12)	1484
N_2 Overspeed Governor and Oil Pump Drive Gear	(13)	1484

* Refer to Figure 4 for location of these gears.

TABLE XVI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
NO. 1 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	103
f_B	675
f_B'	1349
$3f_B'$	4047
f_1	1930
f_2	1340

* Bearing Dimensions (Lycoming P/N 1-300-015-02, New Departure P/N V321ORS5470C09)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2720"
Outer Race I.D. (d_2)	3.2720"
No. of Balls (m)	13

TABLE XVI-a
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
OPTIONAL NO. 1 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	103
f_B	671
f_B'	1341
$3f_B'$	4024
f_1	2081
f_2	1440

* Bearing Dimensions (Lycoming P/N 1-300-015-04, Fafnir P/N MM210VM2SMBRE7730)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2559"
Outer Race I.D. (d_2)	3.2599"
No. of Balls (m)	14

TABLE XVII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
NO. 2 MAIN ENGINE BEARING*
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	110
f_B	998
f_B'	1995
$3f_B'$	5985
f_1	2829
f_2	2201

* Bearing Dimensions (Lycoming P/N 1-300-013-04, Rollway P/N HU1011EAR5706)

Roller Diameter (d_B)	0.3543"
Inner Race O.D. (d_1)	2.4990"
Outer Race I.D. (d_2)	3.2110"
No. of Rollers (m)	20

TABLE XVII-a

FUNDAMENTAL FREQUENCY AT IDLE POWER

MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES

OPTIONAL NO. 2 MAIN ENGINE BEARING*

(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	252
f_T	110
f_B	968
f_B'	1936
$3f_B'$	5809
f_1	2270
f_2	1754

* Bearing Dimensions (Lycoming P/N 1-300-013-05, SKF P/N 457798)

Roller Diameter (d_B)	0.3543"
Inner Race O.D. (d_1)	2.4178"
Outer Race I.D. (d_2)	3.1295"
No. of Rollers (m)	16

TABLE XVIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
NO. 3 MAIN ENGINE BEARING*
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	240
f_T	105
f_B	954
f_B'	1907
$3f_B'$	5721
f_1	2704
f_2	2104

* Bearing Dimensions (Lycoming P/N 1-300-013-04, Rollway P/N HU1011EAR5706)

Roller Diameter (d_B)	0.3543"
Inner Race O . (d_1)	2.4990"
Outer Race I.D. (d_2)	3.2110"
No. of Rollers (m)	20

TABLE XIX
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
NO. 4 MAIN ENGINE BEARING*
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	240
f_T	98
f_B	645
f_B'	1289
$3f_B'$	3868
f_1	1844
f_2	1281

* Bearing Dimensions (Lycoming P/N 1-300-015-02, New Departure P/N V3210RS5470C09)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2720"
Outer Race I.D. (d_2)	3.2720"
No. of Balls (m)	13

TABLE XIX-a

FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
OPTIONAL NO. 4 MAIN ENGINE BEARING*
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Bearing Frequency Identification	Frequency (cps)
f_R	240
f_T	98
f_B	641
f_B'	1282
$3f_B'$	3846
f_1	1989
f_2	1376

* Bearing Dimensions (Lycoming P/N 1-300-015-04, Fafnir P/N MM210VM2SMBRE7730)

Ball Diameter (d_B)	0.5000"
Inner Race O.D. (d_1)	2.2559"
Outer Race I.D. (d_2)	3.2599"
No. of Balls (m)	14

TABLE XX
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
GEAR TRAIN BEARINGS - GAS PRODUCER DRIVEN (N_1)
(N_1 = 60% OF 25147 RPM = 15088 RPM)

Bearing Description	Lycoming P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Outer Driven Bevel	1-300-001-01 (MRC)	(11)	799	559	743	2230
Gear	2-300-023-01 (ND)	(11)	798	559	745	2236
Inner Drive Bevel	1-300-006-01 (MRC)	(12)	1068	832	1076	3229
Gear	1-300-006-02 (SKF)	(12)	1067	832	1080	3241
Inner Drive Bevel	1-300-002-01 (MRC)	(13)	732	490	657	1972
Gear	1-300-002-02 (Fafnir)	(13)	732	490	657	1972
Inner Driven Bevel Gear	1-300-012-01 (MRC)	(14)	357	213	262	787
Inner Driven Bevel	1-300-006-01 (MRC)	(15)	561	437	565	1695
Gear	1-300-006-02 (SKF)	(15)	560	437	567	1702
N_1 Tachometer Gen	1-300-003-01 (MRC)	(16)	338	232	298	895
Idler Gear	1-300-003-02 (Fafnir)	(16)	338	232	298	895
N_1 Tachometer Gen	1-300-005-01 (MRC)	(17)	269	193	246	739
Gear	1-300-005-02 (SKF)	(17)	312	234	289	868
N_1 Tachometer Gen	1-300-003-01 (MRC)	(18)	249	171	220	660
Gear	1-300-003-02 (Fafnir)	(18)	249	171	220	660
Oil Pump Drive &	1-300-003-01 (MRC)	(19)	241	166	213	639
Fuel Control Idler Gear	1-300-003-02 (Fafnir)	(19)	241	166	213	639
Oil Pump Drive &	1-300-004-01 (MRC)	(20)	262	186	234	703
Fuel Control Idler Gear	1-300-004-02 (SKF)	(20)	262	186	234	703
Fuel Control Drive	1-300-005-01 (MRC)	(21)	274	196	250	751
Gear	1-300-005-02 (SKF)	(21)	317	238	294	882

* Refer to Figure 3 for location of these bearings.

TABLE XXI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS T53-L-9, T53-L-9A, AND T53-L-11 ENGINES
GEAR TRAIN BEARINGS - POWER TURBINE DRIVEN (N_2)
(N_2 = 68.4% OF 21088 RPM = 14424 RPM)

Bearing Description	Lycoming P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Drive Sun Gear	1-300-016-01 (Rollway)	(14)	1680	1204	1418	4253
	1-300-016-02 (SKF)	(14)	1700	1185	1216	3650
Planet Gear (Input	1-300-014-01 (NH)	(15)	603	386	430	1292
and Output)	1-300-014-02 (SKF)	(15)	608	382	413	1239
Driven Sun Gear	1-300-023-02 (MRC)	(16)	741	534	450	1352
(Output)	1-300-023-03 (SKF)	(16)	728	546	516	1548
Driven Sun Gear	1-300-011-01 (MRC)	(17)	993	806	715	2146
(Output)	1-300-011-03 (SKF)	(17)	993	807	721	2162
Accessory Outer	1-300-022-01 (Rollway)	(18)	345	291	288	865
Driven Gear	1-300-022-02 (SKF)	(18)	323	265	175	524
Outer Drive Bevel	1-300-021-01 (SKF)	(19)	218	174	219	656
Gear	1-300-021-02 (Fafnir)	(19)	218	174	219	656
Outer Driven Bevel	1-300-004-01 (MRC)	(20)	323	230	289	868
Gear & Inner Drive Bevel Gear	1-300-004-02 (SKF)	(20)	323	230	289	868
Bevel Gear & N_2	1-300-004-01 (MRC)	(21)	308	219	276	826
Tachometer Gen Drive	1-300-004-02 (SKF)	(21)	308	219	276	826
Idler Spur Gear	1-300-003-01 (MRC)	(22)	284	195	251	752
	1-300-003-02 (Fafnir)	(22)	284	195	251	752
N_2 Tachometer Gen	1-300-003-01 (MRC)	(23)	284	195	251	752
& Oil Pump Drive Gear	1-300-003-02 (Fafnir)	(23)	284	195	251	752

* Refer to Figure 4 for location of these bearings.

TABLE XXII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
TRANSMISSION CENTER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Bevel Gear	(1)	2175
Driven Bevel Gear	(2)	2175
Generator Bevel Gear	(3)	2175

* Refer to Figure 5 for location of these gears.

TABLE XXIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS UH-1B AND UH-1C HELICOPTERS
TRANSMISSION CENTER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Bevel Gear	(1)	2175
Driven Bevel Gear	(2)	2175
Generator Bevel Gear	(3)	2175

* Refer to Figures 6 and 7 for location of these gears.

TABLE XXIV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1D HELICOPTER
TRANSMISSION CENTER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Bevel Gear	(1)	2175
Driven Bevel Gear	(2)	2175
Generator Bevel Gear	(3)	2175
Generator Spur Gears	(4, 5 and 6)	3075

* Refer to Figure 8 for location of these gears.

TABLE XXV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
TRANSMISSION UPPER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Transmission Gear	Ref*	Frequency (cps)
Sun Gear (1st Stage)	(7)	1352
Planet Gear (1st-Stage Rotating Carrier)	(8)	1352
Fixed Ring Gear (1st Stage)	(9)	1352
Sun Gear (2nd Stage)	(10)	438
Planet Gear (2nd-Stage Rotating Carrier)	(11)	438
Fixed Ring Gear (2nd Stage)	(12)	438

* Refer to Figure 5 for location of these gears.

TABLE XXVI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS UH-1B, UH-1C AND UH-1D HELICOPTERS
TRANSMISSION UPPER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Transmission Gear	Ref*	Frequency (cps)
Sun Gear (1st Stage)	(7)	1352
Planet Gear (1st-Stage Rotating Carrier)	(8)	1352
Fixed Ring Gear (1st Stage)	(9)	1352
Sun Gear (2nd Stage)	(10)	438
Planet Gear (2nd-Stage Rotating Carrier)	(11)	438
Fixed Ring Gear (2nd Stage)	(12)	438

* Refer to Figures 6, 7 and 8 for location of these gears.

TABLE XXVII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
TRANSMISSION LOWER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Spur Gear	(13)	1929
Driven Spur Gear	(14)	1929
Drive Bevel Gear	(15)	1270
Driven Bevel Gear - Tail Rotor	(16)	1270
Driven Bevel Gear - Accessories	(17)	1270
Drive Spur Gear	(18)	926
Driven Spur Gear	(19)	926
Oil Pump	(46)	188
Hydraulic Pump	(47)	440

* Refer to Figure 5 for location of these gears.

TABLE XXVIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS UH-1B AND UH-1D HELICOPTERS
TRANSMISSION LOWER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Spur Gear	(13)	1929
Driven Spur Gear	(14)	1929
Drive Bevel Gear	(15)	1270
Driven Bevel Gear - Tail Rotor	(16)	1270
Driven Bevel Gear - Accessories	(17)	1270
Drive Spur Gear	(18)	926
Driven Spur Gear	(19)	926
Oil Pump	(46)	188
Hydraulic Pump	(47)	440

* Refer to Figures 6 and 8 for location of these gears.

TABLE XXIX
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1C HELICOPTER
TRANSMISSION LOWER SECTION
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Transmission Gear	Ref*	Frequency (cps)
Drive Spur Gear	(13)	1929
Driven Spur Gear	(14)	1929
Drive Bevel Gear	(15)	1270
Driven Bevel Gear - Tail Rotor	(16)	1270
Driven Bevel Gear - Accessories	(17)	1270
Drive Spur Gear	(20)	1270
Idler Spur Gear	(21)	1270
Driven Spur Gear	(22)	1270
Oil Pump	(46)	188
Hydraulic Pumps No. 1 and No. 2	(47)	440

* Refer to Figure 7 for location of these gears.

TABLE XXX
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
TAIL ROTOR GEAR BOXES
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Gear Box Gears	Ref*	Frequency (cps)
42° Gear Box		
Drive Bevel Gear	(50)	1320
Driven Bevel Gear	(51)	1320
90° Gear Box		
Drive Bevel Gear	(52)	733
Driven Bevel Gear	(53)	733

* Refer to Figure 9 for location of these gears.

TABLE XXXII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
MAIN ROTOR TRANSMISSION BEARINGS
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Input Quill Shaft	204-040-142-1 (MRC/Fafnir)	(23)	889	761	960	2881
	204-040-141-3 (MRC)	(24)	665	460	403	1208
	204-040-269-3 (Rollway/MRC)	(25)	547	353	332	990
	204-040-269-3 (NH)	(25)	503	322	326	979
Main Bevel Gear	204-040-138-3 (Fafnir)	(26)	499	413	367	1101
	204-040-271-3 (MRC/Rollway)	(27)	608	514	415	1245
Generator	204-040-408-1 (MRC)	(28)	759	591	591	1772
	204-040-408-1 (SKF)	(28)	764	585	557	1672
Main Rotor Reduction Gear	204-040-132-1 (Bell Part)**	(33)	338	229	220	659
	204-040-135-1 (MRC/Fafnir)	(34)	286	259	223	669
	204-040-132-1 (Bell Part)**	(35)	109	74	71	213
	204-040-135-1 (MRC/Fafnir)	(36)	93	84	72	217
Mast (Upper Bearing)	204-040-136-7 (Fafnir)	(37)	42	32	26	80
Mast (Lower Bearing)	204-040-270-3 (MRC)	(39)	56	47	39	118

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TABLE XXXII (CONT'D)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B	$3f_B'$
Accessory Drive	204-040-135-1 (MRC/Fafnir)	(38)	885	799	689	2066
	204-040-143-1 (SKF/MRC)	(40)	346	219	201	604
	204-040-310-1 (Rollway/SKF/MRC)	(41)	390	269	248	743
	204-040-310-1 (Rollway/SKF/MRC)	(42)	405	279	258	772
	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-145-1 (SKF/MRC)	(44)	279	185	243	730

* Refer to Figure 5 for location of these bearings.

** Integral part of Bell P/N 204-040-108-5 planetary gears (Reference (8), Figure 5) consisting of P/N 204-040-132-1 inner race and P/N 204-040-725-1 or -3 rollers.

TABLE XXXIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1B HELICOPTER
MAIN ROTOR TRANSMISSION BEARINGS
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Input Quill Shaft	204-040-142-1 (MRC/Fafnir)	(23)	889	761	960	2881
	204-040-346-3 (MRC/SKF)	(24)	665	460	403	1208
	204-040-269-3 (Rollway/MRC)	(25)	547	353	332	996
	204-040-269-3 (NH)	(25)	503	322	326	979
Main Bevel Gear	204-040-345-7 (SKF/Fafnir)	(26)	499	413	367	1101
	204-040-271-3 (MRC/Rollway)	(27)	603	514	415	1245
Generator	204-040-408-1 (MRC)	(28)	759	591	591	1772
	204-040-408-1 (SKF)	(28)	764	585	557	1672
Main Rotor Reduction Gear	204-040-132-1 (Bell Part)**	(33)	338	229	220	659
	204-040-135-1 (MRC/Fafnir)	(34)	286	259	223	669
	204-040-132-1 (Bell Part)**	(35)	109	74	71	213
	204-040-135-1 (MRC/Fafnir)	(36)	93	84	72	217
Mast (Upper Bearing)	204-040-136-7 (Fafnir)	(37)	42	32	26	80
Mast (Lower Bearing)	204-040-270-3 (MRC)	(39)	56	47	39	118

TABLE XXXIII (CONT'D)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Accessory Drive	204-040-135-1 (MRC/Fafnir)	(38)	885	799	689	:066
	204-040-143-1 (SKF/MRC)	(40)	346	219	201	604
	204-040-310-1 (Rollway/SKF/MRC)	(41)	390	269	248	743
	204-040-310-1 (Rollway/SKF/MRC)	(42)	405	279	258	772
	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-145-1 (SKF/MRC)	(44)	264	175	230	692

* Refer to Figure 6 for location of these bearings.
Integral part of Bell P/N 204-040-108-7 planetary gears (Reference (8), Figure 6) consisting of P/N 204-040-132-1 inner race and P/N 204-040-725-1 or -3 rollers.

TABLE XXXIV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1C HELICOPTER
MAIN ROTOR TRANSMISSION BEARINGS
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Input Quill Shaft	204-040-142-1 (MRC/Fafnir)	(23)	889	761	960	2881
	204-040-346-3 (MRC/SKF)	(24)	665	460	403	1208
	204-040-269-3 (Rollway/MRC)	(25)	547	353	332	996
	204-040-269-3 (NH)	(25)	503	322	326	979
Main Bevel Gear	204-040-345-7 (SKF/Fafnir)	(26)	499	413	367	1101
	204-040-271-3 (MRC/Rollway)	(27)	608	514	415	1245
Generator	204-040-408-1 (MRC)	(28)	759	591	591	1772
	204-040-408-1 (SKF)	(28)	764	585	557	1672
Main Rotor Reduction Gear	204-040-132-1 (Bell Part)**	(33)	338	229	220	659
	204-040-135-1 (MRC/Fafnir)	(34)	286	259	223	669
	204-040-132-1 (Bell Part)**	(35)	109	74	71	213
	204-040-135-1 (MRC/Fafnir)	(36)	93	84	72	217
Mast (Upper Bearing)	204-040-136-7 (Fafnir)	(37)	42	32	26	80
Mast (Lower Bearing)	204-040-270-3 (MRC)	(39)	56	47	39	118

TABLE XXXIV (CONT'D)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Accessory Drive	204-040-135-1 (MRC/Fafnir)	(38)	885	799	689	2066
	204-040-143-1 (SKF/MRC)	(40)	346	219	201	604
	204-040-310-1 (Rollway/SKF/MRC)	(41)	390	269	248	743
	204-040-310-1 (Rollway/SKF/MRC)	(42)	405	279	258	772
	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-145-1 (SKF/MRC)	(44)	264	175	230	692
	47-620-661-1 (Fafnir)	(45)	287	201	268	805

* Refer to Figure 7 for location of these bearings.

** Integral part of Bell P/N 204-040-108-7 planetary gears (Reference (8), Figure 7) consisting of P/N 204-040-132-1 inner race and P/N 204-040-725-1 or -3 rollers.

TABLE XXXV
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1D HELICOPTER
MAIN ROTOR TRANSMISSION BEARINGS
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Input Quill Shaft	204-040-142-1 (MRC/Fafnir)	(23)	889	761	960	2881
	204-040-346-3 (SKF/Fafnir)	(24)	665	460	403	1208
	204-040-269-3 (Rollway/MRC)	(25)	547	353	332	996
	204-040-269-3 (NH)	(25)	503	322	326	979
	204-040-345-7 (SKF/Fafnir)	(26)	499	413	367	1101
	204-040-271-3 (MRC/Rollway)	(27)	608	514	415	1245
Generator	205-040-105-1 (MRC)	(29)	612	437	437	1312
	205-040-106-1 (MRC)	(30)	646	479	497	1491
	205-040-107-1 (MRC)	(31)	304	199	258	773
	205-040-108-1 (MRC)	(32)	591	459	591	1772
Main Rotor Reduction Gear	204-040-132-1 (Bell Part)**	(33)	338	229	220	659
	204-040-135-1 (MRC/Fafnir)	(34)	286	259	223	669
	204-040-132-1 (Bell Part)**	(35)	109	74	71	213
	204-040-135-1 (MRC/Fafnir)	(36)	93	84	72	217
Mast (Upper Bearing)	204-040-136-7 (Fafnir)	(37)	42	32	26	80

TABLE XXXV (CONT'D)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Mast (Lower Bearing)	204-040-270-3 (MRC)	(39)	56	47	39	118
Accessory Drive	204-040-135-1 (MRC/Fafnir)	(38)	885	799	689	2066
	204-040-143-1 (SKF/MRC)	(40)	346	219	201	604
	204-040-310-1 (Rollway/SKF/MRC)	(41)	390	269	248	743
	204-040-310-1 (Rollway/SKF/MRC)	(42)	405	279	258	772
	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-145-1 (SKF/MRC)	(44)	264	175	230	692

* Refer to Figure 8 for location of these bearings.

** Integral part of Bell P/N 204-040-108-7 planetary gears (Reference (8), Figure 8) consisting of P/N 204-040-132-1 inner race and P/N 204-040-725-1 or -3 rollers.

TABLE XXXVI
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODEL UH-1A HELICOPTER
MAIN ROTOR SWASH PLATE BEARING
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

		Frequency (cps)			
Bell P/N and Vendor	Ref*	f_1	f_2	f_B'	$3f_B'$
204-010-425-1 (Kaydon)	(48)	195	184	132	397
204-010-425-1 (MRC)	(48)	158	147	106	318

* Refer to Figure 5 for location of this bearing.

TABLE XXXVII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS UH-1B, UH-1C AND UH-1D HELICOPTERS
MAIN ROTOR SWASH PLATE BEARING
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 68.4% OF 6578 RPM)

		Frequency (cps)			
Bell P/N and Vendor	Ref*	f_1	f_2	f_B'	$3f_B'$
204-011-430-1 (Kaydon/MRC/Torrington)	(48)	161	151	113	340

* Refer to Figures 6, 7 and 8 for location of this bearing.

TABLE XXXVIII
FUNDAMENTAL FREQUENCY AT IDLE POWER
MODELS UH-1A, UH-1B, UH-1C AND UH-1D HELICOPTERS
TAIL ROTOR GEAR BOX BEARINGS
TRANSMISSION INPUT DRIVE SHAFT SPEED = 4500 RPM
(ENGINE OUTPUT SHAFT SPEED = 74.5% OF 6038 RPM)

Bearing Description	Bell P/N and Vendor	Ref*	Frequency (cps) f_1	f_2	f_B'	$3f_B'$
Drive Shaft	204-040-615-3 (SKF/MRC)	(46)	313	225	290	870
42° Gear Box	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-310-1 (SKF/MRC)	(42)	405	279	258	772
90° Gear Box	204-040-143-1 (SKF/MRC)	(43)	359	228	209	627
	204-040-406-1 (MRC)	(47)	404	280	260	780
	204-040-406-1 (Bower)	(47)	397	287	288	865
	204-040-406-1 (NH)	(47)	347	240	259	777
	204-040-407-3 (MRC)	(48)	211	165	150	451
	204-040-407-3 (Bower)	(48)	208	167	170	509
	204-040-408-1 (MRC)	(49)	190	148	148	444
	204-040-408-1 (SKF)	(49)	192	147	140	419
	204-040-424-1 (SKF/Fafnir)	(49)	183	136	125	375

* Refer to Figure 9 for location of these bearings.

TABLE XXXIX

MODEL T53 ENGINES RECORDED DURING MICROPHONE SURVEY ON UH-1 HELICOPTERS AT U. S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

Date of Recording	Aircraft Model	Aircraft Serial No.	Engine Model	Engine Serial No.	Engine TT (Hrs)	Engine TSO (Hrs) *
9-14-66	UH-1B	62-1925	T53-L-9A	LE-06135	1801	1142 (1)
9-15-66	UH-1C	65-9534	T53-L-11	LE-10947	215	0 (0)
9-15-66	UH-1D	65-9750	T53-L-11	LE-11289	298	0 (0)
9-16-66	UH-1B	61-0741	T53-L-11	LE-09859	371	0 (1)
9-16-66	UH-1B	62-12533	T53-L-11	LE-09440	878	417 (1)
9-16-66	UH-1B	61-0719	T53-L-9A	LE-06164	894	83 (2)
9-16-66	UH-1C	64-14120	T53-L-11	LE-10466	300	0 (0)
9-19-66	UH-1A	59-1639	T53-L-1A	LE-00299	784	222 (3)
9-19-66	UH-1A	59-1709	T53-L-1A	LE-00430	1141	293 (1)
9-19-66	UH-1D	65-9899	T53-L-11	LE-11492A	303	0 (0)
9-19-66	UH-1C	65-9491	T53-L-11	LE-11221	310	0 (0)
9-20-66	UH-1A	60-3537	T53-L-1A	LE-00378	1129	0 (2)
9-20-66	UH-1A	58-2084	T53-L-1A	LE-00348	2030	977 (1)
9-21-66	HU-1B	62-1928	T53-L-9A	LE-06562	624	0 (0)
9-21-66	UH-1C	65-9502	T53-L-11	LE-113208	300	0 (0)
9-21-66	HU-1B	62-1926	T53-L-11	LE-09894	700	0 (0)

* Numbers in parentheses indicate number of overhauls.

TABLE XL

TRANSMISSIONS AND TAIL ROTOR GEAR BOXES RECORDED DURING MICROPHONE SURVEY ON UH-1 HELICOPTERS AT U. S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

Date	Aircraft Model	Aircraft Serial No.	Transmission Serial No.	Transmission TT (Hrs)	Transmission * TSO (Hrs)
9-14-66	UH-1B	62-1925	A12-348	1626	526 (1)
9-15-66	UH-1C	65-9534	B12-1301	215	0 (0)
9-15-66	UH-1D	65-9750	A12-870	298	0 (0)
9-16-66	UH-1B	61-0741	B12-1120	510	0 (0)
9-16-66	UH-1B	62-12533	A12-1512	180	0 (0)
9-16-66	UH-1B	61-0719	B12-1118	541	0 (0)
9-16-66	UH-1C	64-14120	B12-1004	300	0 (0)
9-19-66	UH-1A	59-1639	A12-328	421	0 (0)
9-19-66	UH-1A	59-1709	A12-240	494	97 (1)
9-19-66	UH-1D	65-9899	A12-980	303	0 (0)
9-19-66	UH-1C	65-9491	B12-922	310	0 (0)
9-20-6.	UH-1A	60-3537	A12-318	444	0 (0)
9-20-66	UH-1A	58-2084	A12-236	2392	985 (1)
9-21-66	HU-1B	62-1928	A12-9	826	0 (0)
9-21-66	UH-1C	65-9502	B12-930	300	0 (0)
9-21-66	HU-1B	62-1926	B12-361	811	0 (0)

NOTE: TT = Total Time

TSO = Time Since Overhaul

* Numbers in parentheses indicate number of overhauls.

Serial numbers and times on tail rotor gear boxes not available.

TABLE XLI
MODEL T53 ENGINES RECORDED DURING FIELD EVALUATION OF CWEA-3/4 ANALYZER ON UH-1 HELICOPTERS AT U. S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

Date of Recording	Aircraft Model	Aircraft Serial No.	Engine Model	Engine Serial No.	Engine TT (Hrs)	Engine TSO (Hrs)
3-20-67	UH-1B	62-1960	T53-L-11	LE-09758	1196	0
3-21-67	UH-1B	61-0741	T53-L-11	LE-09869	UNK	468
3-22-67	UH-1D	65-9898	T53-L-11	LE-11550A	602	0
3-23-67	UH-1A	59-1698	T53-L-1A	LE-00126	UNK	1738
3-23-67	UH-1B	63-8725	T53-L-11	LE-10835	794	0
3-28-67	UH-1D	65-9699	T53-L-11	LE-10523	692	0
3-29-67	UH-1C	64-14115	T53-L-11	LE-10496	623	0
3-29-67	UH-1B	61-0744	T53-L-11	LE-10921	644	0
3-29-67	UH-1D	65-9825	T53-L-11	LE-11214	655	0
3-30-67	UH-1A	58-3047	T53-L-1A	LE-00227	UNK	270
3-31-67	UH-1D	65-9899	T53-L-11	LE-11492A	UNK	0
4-4-67	UH-1A	58-3045	T53-L-1A	LE-00275	1266	123
4-4-67	UH-1B	60-3562	T53-L-9A	LE-06282	UNK	283
4-5-67	UH-1D	65-9761	T53-L-11	LE-11290	832	0
4-19-67	UH-1B	62-1949	T53-L-11	LE-09415	UNK	1025
4-20-67	UH-1B	62-1927	T53-L-11	LE-09930	869	0
5-4-67	* UH-1B	60-3562	T53-L-11	LE-06282	UNK	325
5-4-67	* UH-1D	65-9899	T53-L-11	LE-11492A	914	N.A.
6-28-67	UH-1B	62-1950	T53-L-11	LE-10822	1147	0
6-28-67	HU-1B	62-1928	T53-L-9A	LE-06238	1082	597
6-29-67	* UH-1B	62-1950	T53-L-11	LE-10822	1148	1
7-11-67	UH-1B	61-0760	T53-L-11	LE-11075	964	0
7-13-67	UH-1D	65-10032	T53-L-11	LE-11718A	921	0

* Repeat Runs

TABLE XLI (CONT'D)

Date of Recording	Aircraft Model	Aircraft Serial No.	Engine Model	Engine Serial No.	Engine TT (Hrs)	Engine TSO (Hrs)
7-13-67	HU-1A	59-1667	T53-L-1A	LE-00300	2215	38
7-17-67	UH-1B	62-1874	T53-L-9A	LE-06092	1637	636
7-18-67	UH-1B	61-0724	T53-L-9A	LE-03117	726	471
7-18-67	UH-1B	62-1962	T53-L-11	LE-11303	1199	0
7-19-67	UH-1B	62-4604	T53-L-9A	LE-06224	1397	1118
7-25-67	UH-1B	61-0745	T53-L-11	LE-09645	1332	666
7-25-67	UH-1D	66-1038	T53-L-11B	LE-12595	-	-
7-25-67	UH-1B	61-0719	T53-L-9A	LE-06514	-	-
7-26-67	UH-1A	60-3537	T53-L-1A	LE-00429	1662	306
7-26-67	UH-1A	59-1703	T53-L-1A	LE-00285	674	93
8-17-67	UH-1B	61-0730	T53-L-9A	LE-06276	1078	21
8-17-67	UH-1B	63-8704	T53-L-11	LE-06541	1010	8
8-23-67	UH-1B	63-8548	T53-L-11	LE-09498	1980	894
8-24-67	UH-1B	62-1888	T53-L-11	LE-09985	1417	857
8-24-67	UH-1B	62-1964	T53-L-11	LE-11362A	737	0
8-24-67	* UH-1B	63-8548	T53-L-11	LE-09498	1980	894
8-24-67	UH-1B	60-3562	T53-L-9A	LE-06282	UNK	710
8-25-67	UH-1B	61-0763	T53-L-11	LE-10355	1053	761
8-25-67	* UH-1B	61-0730	T53-L-9A	LE-06276	1105	49
8-30-67	* UH-1B	62-1964	T53-L-11	LE-11362A	751	0
8-31-67	* UH-1B	61-0745	T53-L-11	LE-09645	1451	785
8-31-67	* UH-1B	61-0724	T53-L-9A	LE-03117	1094	569
8-31-67	UH-1B	62-1954	T53-L-9A	LE-06024	UNK	860
9-5-67	* UH-1B	60-3562	T53-L-9A	LE-06282	UNK	724

* Repeat Runs

TABLE XLI (CONT'D)

Date of Recording	Aircraft Model	Aircraft Serial No.	Engine Model	Engine Serial No.	Engine TT (Hrs)	Engine TSO (Hrs)
9-5-67	* UH-1B	61-0730	T53-L-9A	LE-06276	1122	65
9-6-67	* UH-1B	62-1964	T53-L-11	LE-11362A	791	40
9-8-67	* UH-1B	61-0745	T53-L-11	LE-09645	1470	794
9-8-67	* UH-1B	62-1964	T53-L-11	LE-11362A	791	40
9-11-67	* UH-1B	60-3562	T53-L-9A	LE-06282	UNK	755
9-12-67	UH-1B	60-3547	T53-L-11	LE-10173	1141	UNK
9-13-67	UH-1B	61-0741	T53-L-9A	LE-06196	995	0
9-13-67	UH-1A	59-1630	T53-L-1A	LE-00199	1804	151
9-15-67	* UH-1B	61-0724	T53-L-9A	LE-03117	854	597

* Repeat Runs

TABLE XLII

TRANSMISSIONS AND TAIL ROTOR GEAR BOXES RECORDED DURING FIELD I
ON UH-1 HELICOPTERS AT U. S. ARMY AVIATION CENTER, F

Date of Recording	Aircraft Model	Aircraft Serial No.	Transmission Serial No.	Transmission Total Time (Hrs.)		42° Gear Box Serial No.
3-20-67	UH-1B	62-1960	B12-448	294	(0 TSO)	B13-1256
3-21-67	UH-1B	61-0741	B12-1120	978	(0 TSO)	B13-1686
3-22-67	UH-1D	65-9898	A12-987	602	(0 TSO)	B13-4656
3-23-67	UH-1A	59-1698	A12-133	1147	(TSO)	B13-3709
3-23-67	UH-1B	63-8725	B12-172	1105	(0 TSO)	B13-3327
3-28-67	UH-1D	65-9699	A12-830	692	(0 TSO)	B13-3930
3-29-67	UH-1C	64-14115	B12-487	623	(0 TSO)	B13-3698
3-29-67	UH-1B	61-0744	B12-1134	336		B13-2799
3-29-67	UH-1D	65-9825	A12-917	655	(0 TSO)	B13-4564
3-30-67	UH-1A	58-3047	A12-163	1010	(400 TSO)	B13-2708
3-31-67	UH-1D	65-9899	A12-980	851		B13-1029
4-4-67	UH-1A	58-3045	A12-323	817	(0 TSO)	B13-404
4-4-67	UH-1B	60-3562	B12-1121	1023		B13-1657
4-5-67	UH-1D	65-9761	A12-335	832	(0 TSO)	B13-4555
4-19-67	UH-1B	62-1949	B12-443	907		B13-1865
4-20-67	UH-1B	62-1927	B12-09930	869	(0 TSO)	-
5-4-67	* UH-1B	60-3562	B12-1121	1065	(42 TSO)	B13-1657
5-4-67	* UH-1D	65-9899	A12-980	NA		B13-1029
6-28-67	UH-1B	62-1950	A12-669	1710	(884 TSO)	B13-4008
6-28-67	HU-1B	62-1928	A12-524	1413	(302 TSO)	B13-2800
6-29-67	* UH-1B	62-1950	A12-669	1710	(884 TSO)	A13-888
7-11-67	UH-1B	61-0760	A12-1441	370	(198 TSO)	B13-2205
7-13-67	UH-1D	65-10032	B12-449	929	(0 TSO)	B13-5333
7-13-67	HU-1A	59-1667	A12-83	495	(0 TSO)	B13-5516
7-17-67	UH-1B	62-1874	A12-69	UNK		B13-590
7-18-67	UH-1B	61-0724	B12-627	1080	(460 TSO)	B13-3423
7-18-67	UH-1B	62-1962	A12-88	UNK	(500 TSO)	B19-5189
7-19-67	UH-1B	62-4604	B12-1172	531	(0 TSO)	B13-891
7-25-67	UH-1B	61-0745	A12-618	1347	(247 TSO)	B13-4313
7-25-67	UH-1D	66-1038	A12-1386	UNK		B13-6610
7-25-67	UH-1B	61-0719	B12-1118	UNK		A13-418
7-26-67	UH-1A	60-3537	A12-97	677	(27 TSO)	B13-3095
7-26-67	UH-1A	59-1703	A12-122	1387	(0 TSO)	B13-2950
8-17-67	UH-1B	61-0730	A12-801	1991	(906 TSO)	B13-2556
8-17-67	UH-1B	63-8704	A12-178	1259	(436 TSO)	B13-1455
8-23-67	UH-1B	63-8548	B12-403	1109	(1 TSO)	B13-563
8-24-67	UH-1B	62-1888				
8-24-67	UH-1B	62-1964	B12-613	736		B13-737

A

TABLE XLII

ES RECORDED DURING FIELD EVALUATION OF CWEA-3/4 ANALYZER

S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

ission me (Hrs.)	42° Gear Box Serial No.	42° Gear Box Total Time (Hrs)		90° Gear Box Serial No.	90° Gear Box Total Time (Hrs)	
(0 TSO)	B13-1256	UNK		B13-020	UNK	
(0 TSO)	B13-1686	430	(TSO)	B13-5041	429	
(0 TSO)	B13-4656	602		B13-4512	602	
(TSO)	B13-3709	1147	(TSO)	B13-504	1627	(TSO)
(0 TSO)	B13-3327	1105		B13-2267	1105	
(0 TSO)	B13-3930	692		B13-3959	692	
(0 TSO)	B13-3698	623		B13-3143	623	
	B13-2799	550		B13-2799	837	
(0 TSO)	B13-4564	655	(0 TSO)	B13-4416	655	(0 TSO)
(400 TSO)	B13-2708	732		B13-819	819	
	B13-1029	1046		B13-4530	851	
(0 TSO)	B13-404	22		B13-855	897	
	B13-1657	573		B13-1661	617	
(0 TSO)	B13-4555	832	(0 TSO)	B13-4449	832	(0 TSO)
	B13-1865	907	(TSO)	B13-781	907	(TSO)
(0 TSO)	-	648	(0 TSO)	B13-1246	1438	(338 TSO)
(42 TSO)	B13-1657	615		B13-1661	659	
	B13-1029	NA		B13-4530	NA	
(884 TSO)	B13-4008	589	(0 TSO)	B13-3333	724	(0 TSO)
(302 TSO)	B13-2800	1307	(0 TSO)	B13-4233	909	(0 TSO)
(884 TSO)	A13-888	-		B13-3333	724	(0 TSO)
(198 TSO)	B13-2205	978	(776 TSO)	B13-5532	602	(0 TSO)
(0 TSO)	B13-5333	929	(0 TSO)	B13-5275	929	(0 TSO)
(0 TSO)	B13-5516	268	(0 TSO)	A13-74	1373	(268 TSO)
	B13-590	2302	(1234 TSO)	A13-180	30	(0 TSO)
(460 TSO)	B13-3423	524	(0 TSO)	A13-208	201	(0 TSO)
(500 TSO)	B19-5189	500	(0 TSO)	B13-4035	1071	(0 TSO)
(0 TSO)	B13-891	798	(0 TSO)	B13-2789	795	(0 TSO)
(247 TSO)	B13-4313	668	(0 TSO)	B13-4108	668	(0 TSO)
	B13-6610	UNK		B13-7096	UNK	
	A13-418	UNK		A13-404	UNK	
(27 TSO)	B13-3095	966	(0 TSO)	B13-572	1866	(524 TSO)
(0 TSO)	B13-2950	1038	(850 TSO)	B13-589	1950	(660 TSO)
(906 TSO)	B13-2556	27		A13-206	27	
(436 TSO)	B13-1455	898		B13-2761	570	(499 TSO)
(1 TSO)	B13-563	1382		B13-2373	1693	(593 TSO)
	B13-737	UNK	(718 TSO)	B13-1657	UNK	(718 TSO)

B

TABLE XLII (CONT'D)

Date of Recording	Aircraft Model	Aircraft Serial No.	Transmission Serial No.	Transmission Total Time (Hrs.)		42° Gear Box Serial No.
8-24-67	UH-1B	* 63-8548	B12-403	1109	(1 TSO)	B13-563
8-24-67	UH-1B	60-3562	A12-342	1750	(332 TSO)	B13-1657
8-25-67	UH-1B	61-0763	A12-83	1293	(467 TSO)	B13-1944
8-25-67	UH-1B	* 61-0730	A12-801	2003	(918 TSO)	B13-2556
8-30-67	UH-1B	62-1964	B12-613	750		B13-737
8-31-67	UH-1B	* 61-0745	A12-618	1473	(373 TSO)	B13-4313
8-31-67	UH-1B	* 61-0724	B12-627	1178	(558 TSO)	B13-3423
8-31-67	UH-1B	62-1954	A12-208	1958	(860 TSO)	B13-2966
9-5-67	UH-1B	* 60-3562	A12-342	1785	(367 TSO)	B13-1657
9-5-67	UH-1B	* 61-0730	A12-801	2035	(950 TSO)	B13-2556
9-6-67	UH-1B	* 62-1964	B12-613	806		B13-737
9-8-67	UH-1B	* 61-0745	A12-618	1492	(392 TSO)	B13-4313
9-8-67	UH-1B	* 62-1964	B12-613	806		B13-737
9-11-67	UH-1B	* 60-3562	A12-342	1816	(398 TSO)	B13-1657
9-12-67	UH-1B	60-3547	A12-207	1652	(538 TSO)	B13-3413
9-13-67	UH-1B	61-0741	A12-483	1695	(313 TSO)	B13-1686
9-13-67	UH-1A	59-1630	A12-77	1798	(639 TSO)	B13-2465
9-15-67	UH-1B	* 61-0724	B12-627	1208	(588 TSO)	B13-3423

* **Repeat Recordings**

A

TABLE XLII (CONT'D)

nsmission l Time (Hrs.)	42° Gear Box Serial No.	42° Gear Box Total Time (Hrs)		90° Gear Box Serial No.	90° Gear Box Total Time (Hrs)	
(1 TSO)	B13-563	1382		B13-2373	1693	(593 TSO)
(332 TSO)	B13-1657	UNK	(979 TSO)	B13-1661	UNK	(1023 TSO)
(467 TSO)	B13-1944	1029	(761 TSO)	B13-3818	1064	
(918 TSO)	B13-2556	32		A13-206	32	
	B13-737	UNK	(732 TSO)	B13-1657	UNK	(732 TSO)
(373 TSO)	B13-4313	794		B13-4108	794	
(558 TSO)	B13-3423	622	(0 TSO)	A13-208	299	(0 TSO)
(860 TSO)	B13-2966	860		B13-3308	862	
(367 TSO)	B13-1657	UNK	(1014 TSO)	B13-1661	UNK	(1058 TSO)
(950 TSO)	B13-2556	64		A13-206	64	
	B13-737	UNK	(772)	B13-1657	UNK	(772)
(392 TSO)	B13-4313	1013		B13-4108	1013	
	B13-737	UNK	(772 TSO)	B13-1657	UNK	(772 TSO)
(398 TSO)	B13-1657	UNK	(1045)	B13-1661	UNK	(1089 TSO)
(538 TSO)	B13-3413	748		A13-155	244	
(313 TSO)	B13-1686	1915	(816 TSO)	B13-5041	815	
(639 TSO)	B13-2465	1740	(639 TSO)	A13-111	1429	(639 TSO)
(588 TSO)	B13-3423	652		A13-208	329	

B

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TABLE XLIII

MODEL T53-L-1A ENGINE N_1 COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 2 Normalize		2	N1	1.1223	5-25	Set 5
	Noise Check (Storage)		2	N1	1.1223	5-25	
1	No. 2 Compressor Fundamental		2	N1	1.0000	5-5	Set FS
2		$-f_R$	2	N1	.7556	5-5	Reject 5
3		$+f_R$	2	N1	1.0222	5-5	Reject 5
	Clear		-	-	-	-	
4	No. 1 Main Bearing	f_1	2	N1	.2142	5-20	Reject 8
5		f_2	2	N1	.1413	5-20	Reject 8
6		f_B'	2	N1	.1420	5-20	Reject 8
7		$3f_B'$	2	N1	.4462	5-20	Reject 8
8	No. 1 Main Bearing	f_1	2	N1	.2272	5-20	Reject 8
9	(Option)	f_2	2	N1	.1506	5-20	Reject 8
10		$3f_B'$	2	N1	.4444	5-20	Reject 8
11	No. 2 Main Bearing	f_1	2	N1	.3155	5-15	Reject 8
12		f_2	2	N1	.2400	5-15	Reject 8
13		f_B'	2	N1	.2210	5-15	Reject 8
14		$3f_B'$	2	N1	.6631	5-20	Reject 8
15	Oil Pump (Vane Type)(27)		2	N1	.0137	5-20	Reject 8
16	Oil Pump (Gear Type)(27)		2	N1	.0355	5-20	Reject 8
17	Fuel Control Pump Gears (25)		2	N1	.0327	5-10	Reject 8
18	Fuel Control Accessory Drive Gears (26)		2	N1	.0503	5-15	Reject 8
19	Fuel Control Main Drive Gears (22, 23, 24)		2	N1	.1206	5-10	Reject 8
20	N1 Tachometer Drive Gears - ADGB (6, 7)		2	N1	.1640	5-20	Reject 8
21	Spur Idler Gears - ADGB (4b, 5, 8)		2	N1	.1742	5-20	Reject 8
22	Fuel Control Drive Gears ADGB (9, 10)		2	N1	.1664	5-15	Reject 8
23	Bevel Drive Gears - ADGB (3, 4a)		2	N1	.3172	5-15	Reject 8

TABLE XLIV
MODEL T53-L-1A ENGINE N_2 COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 2 Normalize		2	N1	1.1223	5-25	Set 5
1	No. 3 Main Bearing	f_1	2	N2	.3250	5-15	Reject 8
2		f_2	2	N2	.2456	5-15	Reject 8
3		f_B'	2	N2	.2262	5-15	Reject 8
4		$3f_B'$	2	N2	.7026	5-20	Reject 8
5	No. 4 Main Bearing	f_1	2	N2	.2212	5-15	Reject 8
6		f_2	2	N2	.1447	5-15	Reject 8
7		f_B'	2	N2	.1455	5-15	Reject 8
8		$3f_B'$	2	N2	.4606	5-20	Reject 8
9	Output Sun Gear Bearing	f_1	2	N2	.1610	5-10	Reject 8
10		f_2	2	N2	.1143	5-15	Reject 8
11		f_B'	2	N2	.1360	5-10	Reject 8
12		$3f_B'$	2	N2	.4317	5-15	Reject 8
13	Overspeed Governor Drive Gears-ADGB (8, 9)		2	N2	.1523	5-10	Reject 8
14	ADGB Bevel Drive Gears (4, 5)		2	N2	.3160	5-10	Reject 8
15	Output Gears (1, 2, 3)		2	N2	1.1361	5-15	Reject 8
	Storage		2	N1	1.1223	5-25	
16	Output Gears Fundamental (1, 2, 3)		2	N2	1.1361	5-15	Set FS
17	Output Bell Gear (3)	$-f_R$	2	N2	1.1302	5-15	Reject 8
18	Output Bell Gear (3)	$+f_R$	2	N2	1.1440	5-15	Reject 8
19	Planet Gears (2)	$-f_R$	2	N2	1.1147	5-15	Reject 8
20	Planet Gears (2)	$+f_R$	2	N2	1.1574	5-15	Reject 8
21	Input Sun Gear (1)	$-f_R$	2	N2	1.1132	5-15	Reject 8
22	Input Sun Gear (1)	$+f_R$	2	N2	1.1611	5-15	Reject 8

TABLE XLV
MODELS T53-L-9, T53-L-9A AND T53-L-11 ENGINES
N_1 COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 2 Normalize		2	N1	1.1223	5-25	Set 5
	Noise Check (Storage)		2	N1	1.1223	5-25	
1	No. 2 Compressor Fundamental		2	N1	1.0000	5-5	Set FS
2		$-f_R$	2	N1	.7556	5-5	Reject 5
3		$+f_R$	2	N1	1.0222	5-5	Reject 5
	Clear		-	-	-	-	
4	No. 1 Main Bearing	f_1	2	N1	.2142	5-20	Reject 8
5		f_2	2	N1	.1413	5-20	Reject 8
6		f_B'	2	N1	.1420	5-20	Reject 8
7		$3f_B'$	2	N1	.4462	5-20	Reject 8
8	No. 1 Main Bearing	f_1	2	N1	.2272	5-20	Reject 8
9	(Option)	f_2	2	N1	.1506	5-20	Reject 8
10		$3f_B'$	2	N1	.4444	5-20	Reject 8
11	No. 2 Main Bearing	f_1	2	N1	.3155	5-15	Reject 8
12		f_2	2	N1	.2400	5-15	Reject 8
13		f_B'	2	N1	.2210	5-15	Reject 8
14		$3f_B'$	2	N1	.6631	5-20	Reject 8
15	No. 2 Main Bearing	f_1	2	N1	.2450	5-15	Reject 8
16	(Option)	f_B'	2	N1	.2146	5-15	Reject 8
17		$3f_B'$	2	N1	.6463	5-20	Reject 8
18	Oil Pump (Vane Type)(27)		2	N1	.0137	5-20	Reject 8
19	Oil Pump (Gear Type)(27)		2	N1	.0355	5-20	Reject 8
20	Fuel Control Pump Gears (25)		2	N1	.0370	5-20	Reject 8
21	Fuel Control Accessory Drive Gears (26)		2	N1	.0565	5-25	Reject 8
22	Fuel Control Main Drive Gears (22, 23, 24)		2	N1	.1352	5-20	Reject 8
23	N1 Tachometer Drive Gears-ADGB (6, 7)		2	N1	.1640	5-20	Reject 8

TABLE XLV (CONT'D)

Item No.	Component	Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
24	Spur Idler Gears - ADGB (4b, 5, 8)	2	N1	.1742	5-20	Reject 8
25	Fuel Control Drive Gears (9, 10)	2	N1	.1772	5-15	Reject 8
26	Bevel Drive Gears - ADGB (3, 4a)	2	N1	.3172	5-15	Reject 8

TABLE XLVI
MODELS T53-L-9, T53-L-9A AND T53-L-11 ENGINES
N_2 COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 2 Normalize		2	N1	1.1223	5-25	Set 5
1	No. 3 Main Bearing	f_1	2	N2	.3241	5-15	Reject 8
2		f_2	2	N2	.2451	5-15	Reject 8
3		f_B'	2	N2	.2255	5-15	Reject 8
4		$3f_B'$	2	N2	.7007	5-20	Reject 8
5	No. 4 Main Bearing	f_1	2	N2	.2206	5-15	Reject 8
6		f_2	2	N2	.1444	5-15	Reject 8
7		f_B'	2	N2	.1451	5-15	Reject 8
8		$3f_B'$	2	N2	.4574	5-20	Reject 8
9	No. 4 Main Bearing	f_1	2	N2	.2341	5-15	Reject 8
10	(Option)	f_2	2	N2	.1540	5-15	Reject 8
11		$3f_B'$	2	N2	.4556	5-20	Reject 8
12	ADGB Bevel Drive Gears (7,8)		2	N2	.1127	5-25	Reject 8
13	Bevel Drive Gears - ADGB (9,10)		2	N2	.1167	5-20	Reject 8
14	Spur Idler Gears - ADGB (11,12,13)		2	N2	.1644	5-20	Reject 8
15	Output Gears - Low Speed (3,4)		2	N2	.3022	5-15	Reject 8
16	Output Gears - High Speed (1,2)		2	N2	.6141	5-15	Reject 8

TABLE XLVII
TRANSMISSION COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 1 Normalize		1	N1	1.1223	5-25	Set 5
1	Main Rotor Low Speed Gears (10,11,12)		1	N2	.0423	5-10	Reject 8
2	Main Rotor Low Speed Gears X2		1	N2	.1046	3-15	Reject 8
3	Lower Transmission Output Drive Gears (15,16,17)		1	N2	.1435	5-10	Reject 8
4	Lower Transmission Output Drive Gears X2		1	N2	.3072	5-15	Reject 8
5	Main Rotor High Speed Gears (7,8,9)		1	N2	.1520	5-15	Reject 8
6	Lower Transmission Offset Spur (13,14)		1	N2	.2273	5-15	Reject 8
7	Input Drive Bevel Gears (1,2,3)		1	N2	.2525	5-5	Reject 8
8	Input Drive Bevel Gears X2		1	N2	.5253	5-15	Reject 8
9	Generator Drive Gears (UH-1D) (4,5,6)		1	N2	.3612	2-20	Reject 8
10	Oil Pump		1	N2	.0166	3-10	Reject 8
11	Hydraulic Pump		1	N2	.0424	4-15	Reject 8
12	Bearing-Swash Plate	f_1	1	N2	.0172	2-15	Reject 8
13	UH-1A (48)	f_2	1	N2	.0164	1-15	Reject 8
14		f_B'	1	N2	.0123	2-10	Reject 8
15		$3f_B'$	1	N2	.0371	4-15	Reject 8
16	Bearing-Optional Swash	f_1	1	N2	.0143	4-10	Reject 8
17	Plate UH-1A (48)	f_2	1	N2	.0134	3-10	Reject 8
18		f_B'	1	N2	.0102	5-5	Reject 8
19		$3f_B'$	1	N2	.0310	4-15	Reject 8
20	Bearing-Swash Plate	f_1	1	N2	.0145	5-10	Reject 8
21	UH-1B/1C/1D (48)	f_2	1	N2	.0137	4-10	Reject 8
22		f_B'	1	N2	.0107	5-5	Reject 8
23		$3f_B'$	1	N2	.0325	4-15	Reject 8

TABLE XLVIII
TRANSMISSION BEARING GAIN SETTINGS - GROUP I

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 1 Normalize		1	N1	1.1223	5-25	Set 5
1	Bearing (37)	f_1	1	N2	.0032	5-5	Reject 8
2		f_2	1	N2	.0024	5-5	Reject 8
3		f_B'	1	N2	.0021	5-5	Reject 8
4		$3f_B'$	1	N2	.0062	5-5	Reject 8
5	Bearing (39)	f_1	1	N2	.0043	5-5	Reject 8
6		f_2	1	N2	.0035	5-5	Reject 8
7		f_B'	1	N2	.0031	5-5	Reject 8
8		$3f_B'$	1	N2	.0112	1-10	Reject 8
9	Bearing (23)	f_1	1	N2	.1056	3-20	Reject 8
10		f_2	1	N2	.0736	5-15	Reject 8
11		f_B'	1	N2	.1133	4-20	Reject 8
12		$3f_B'$	1	N2	.3421	6-20	Reject 8
13	Bearing (24)	f_1	1	N2	.0641	5-25	Reject 8
14		f_2	1	N2	.0441	5-20	Reject 8
15		f_B'	1	N2	.0375	4-15	Reject 8
16		$3f_B'$	1	N2	.1366	4-20	Reject 8
17	Bearing (40)	f_1	1	N2	.0331	4-20	Reject 8
18		f_2	1	N2	.0212	2-15	Reject 8
19		f_B'	1	N2	.0176	2-15	Reject 8
20		$3f_B'$	1	N2	.0573	5-15	Reject 8
21	Bearing (42)	f_1	1	N2	.0376	4-15	Reject 8
22		f_2	1	N2	.0257	3-15	Reject 8
23		f_B'	1	N2	.0242	3-15	Reject 8
24		$3f_B'$	1	N2	.0744	5-15	Reject 8
25	Bearing (43)	f_1	1	N2	.0341	4-15	Reject 8
26		f_2	1	N2	.0217	3-15	Reject 8
27		f_B'	1	N2	.0203	2-15	Reject 8
28		$3f_B'$	1	N2	.0611	5-25	Reject 8

TABLE XLIX
TRANSMISSION BEARING GAIN SETTINGS - GROUP II

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 1 Normalize		1	N1	1.1223	5-25	Set 5
1	Bearing (25)	f_1	1	N2	.0527	4-15	Reject 8
2		f_2	1	N2	.0336	4-15	Reject 8
3		f_B'	1	N2	.0320	4-15	Reject 8
4		$3f_B'$	1	N2	.1161	4-20	Reject 8
5	Bearing (25)	f_1	1	N2	.0474	4-15	Reject 8
6	(Option)	f_2	1	N2	.0312	1-20	Reject 8
7		f_B'	1	N2	.0315	1-20	Reject 8
8		$3f_B'$	1	N2	.1147	4-20	Reject 8
9	Bearing (26)	f_1	1	N2	.0471	4-15	Reject 8
10		f_2	1	N2	.0403	5-15	Reject 8
11		f_B'	1	N2	.0346	5-15	Reject 8
12		$3f_B'$	1	N2	.1263	4-20	Reject 8
13	Bearing (26)	f_1	1	N2	.0474	4-15	Reject 8
14	(Option)	f_2	1	N2	.0401	5-15	Reject 8
15		f_B'	1	N2	.0323	4-15	Reject 8
16		$3f_B'$	1	N2	.1171	4-20	Reject 8
17	Bearing (27)	f_1	1	N2	.0576	5-15	Reject 8
18		f_2	1	N2	.0503	4-15	Reject 8
19		f_B'	1	N2	.0404	5-15	Reject 8
20		$3f_B'$	1	N2	.1415	4-20	Reject 8
21	Bearing (34)	f_1	1	N2	.0264	3-15	Reject 8
22		f_2	1	N2	.0243	3-15	Reject 8
23		f_B'	1	N2	.0214	2-15	Reject 8
24		$3f_B'$	1	N2	.0644	5-25	Reject 8
25	Bearing (36)	f_1	1	N2	.0072	5-5	Reject 8
26		f_2	1	N2	.0065	5-5	Reject 8
27		f_B'	1	N2	.0055	5-5	Reject 8
28		$3f_B'$	1	N2	.0210	5-5	Reject 8

TABLE XLIX (CONT'D)

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
29	Bearing (38)	f_1	1	N2	.1053	2-20	Reject 8
30		f_2	1	N2	.0766	2-20	Reject 8
31		f_B'	1	N2	.0670	5-15	Reject 8
32		$3f_B'$	1	N2	.2421	2-25	Reject 8
33	Bearing (41)	f_1	1	N2	.0365	4-15	Reject 8
34		f_2	1	N2	.0251	3-15	Reject 8
35		f_B'	1	N2	.0234	3-15	Reject 8
36		$3f_B'$	1	N2	.0722	4-15	Reject 8

TABLE L
TAIL ROTOR DRIVE COMPONENT GAIN SETTINGS

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 3 Normalize		3	N1	1.1223	5-25	Set 5
1	Bearing - Shaft	f_1	3	N2	.0304	1-5	Reject 8
2	Support (46)	f_2	3	N2	.0215	1-5	Reject 8
3		f_B'	3	N2	.0266	1-5	Reject 8
4		$3f_B'$	3	N2	.1043	2-15	Reject 8
5	Bearing - Quill	f_1	3	N2	.0376	5-10	Reject 8
6	Assembly-Single Row	f_2	3	N2	.0257	1-5	Reject 8
7	42° Gear Box (42)	f_B'	3	N2	.0241	1-5	Reject 8
8		$3f_B'$	3	N2	.0743	5-5	Reject 8
9	Bearing - Quill	f_1	3	N2	.0341	5-5	Reject 8
10	Assembly-Double Row	f_2	3	N2	.0217	3-5	Reject 8
11	42° and 90° Gear						
	Boxes (43)	f_B'	3	N2	.0203	3-0	Reject 8
12		$3f_B'$	3	N2	.0611	5-10	Reject 8
13	Bevel Gears - 42° Gear						
	Box Fundamental		3	N2	.1474	4-0	Reject 8
	Noise Check (Storage)		3	N2	.1553	4-0	
14	Bevel Gears - 42° Gear						
	Box Fundamental		3	N2	.1474	4-0	
15	(50,51)	$-f_R$	3	N2	.1436	4-0	Reject 1/2 of 14
16		$+f_R$	3	N2	.1533	4-0	Reject 1/2 of 14
17		X2	3	N2	.3171	4-0	Reject 1/2 of 14
	Clear		-	-	-	-	
18	Bevel Gears - 90° Gear						
	Box Fundamental		3	N2	.0714	2-0	Reject 8
	Noise Check (Storage)		3	N2	.0773	2-0	
19	Bevel Gears - 90° Gear						
	Box Fundamental		3	N2	.0714	2-0	
20	(52,53)	$-f_R$	3	N2	.0655	2-0	Reject 1/2 of 19
21		$+f_R$	3	N2	.0753	2-0	Reject 1/2 of 19
22		X2	3	N2	.1630	2-0	Reject 1/2 of 19

TABLE LI

MODELS T53-L-9A AND T53-L-11 ENGINES N_1 COMPONENT CONDITION METER READINGS SUMMARY

	Condition Meter Readings											
	Engine Serial Number (LE Series) and Aircraft Serial Number											
	10822	06238	10822	11075	06092	03117	11303	06224	09645	12595	06514	06276
Item*	62-1950	62-1928	62-1950	61-0760	62-1874	61-0724	62-1962	62-4604	61-0745	66-1038	61-0719	61-0730
Noise	6.5	6	5	5.5	5	6.5	5	6	-	-	-	-
1	4.5	9	P	2	P	8.5	6	6	8	2.5	10	9
2	1	1	1	0.5	1	1	1	1	1	0.5	1.5	1
3	1	1	3.5	1	1.5	1	0.5	1	1	0.5	1.5	1
4	7.5	6.5	1.5	2	4.5	3.5	2	2	4	1.5	2.5	2.5
5	3.5	6.5	8	1	3.5	4	1.5	3	1.5	2	1.5	1.5
6	6.5	6	P	2	2.5	3.5	1.5	2.5	1	1.5	1.5	2
7	5	4	2.5	4	4.5	6.5	3	4	4	3	3.5	3
8	3.5	5	1.5	2.5	5.5	5.5	2.5	4.5	3.5	1.5	2.5	7.5
9	3.5	4	3.5	2	3.5	3	2	3.5	2	1	1.5	4
10	4	4	2	2.5	4.0	6	3.5	3.5	3.5	2.5	7	3
11	3	2	2	2.5	3	4.5	3.5	2	4	2	2	3.5
12	2	2.5	1	2	5	3	2	2.5	3.5	2	2	2.5
13	2.5	3	0.5	1	1.5	5	1	2	1.5	1.5	1	1.5
14	4.5	3.5	2.5	4	4	3.5	2.5	3	5	3.5	3.5	3
15	3	4	1.5	2	4	2.5	1.5	2	4	7	3.5	3
16	4	3.5	1	1	2.5	1.5	1.5	1	2	0.5	1.5	2
17	3.5	3	3	3.5	4.5	4	3.5	4	5	2.5	4	5
18	7	9	P	5.5	P	P	7	7	P	5.5	7	P
19	2	5	P	2	3.5	4	2	2	2	2	2	2
20	3	3	7.5	1.5	3.5	2.5	1.5	2.5	3.5	1.5	1.5	5
21	2	2	7	5.5	3	2.5	1	1.5	1.5	1.5	2	2
22	2.5	4	4	2	10	2.5	1.5	1.5	5	1.5	2.5	2

TABLE LI (CONT'D)

	Condition Meter Readings											
	Engine Serial Number (LE Series) and Aircraft Serial Number											
	10822	06238	10822	11075	06092	03117	11303	06224	09645	12595	06514	06276
Item*	62-1950	62-1928	62-1950	61-0760	62-1874	61-0724	62-1962	62-4604	61-0745	66-1038	61-0719	61-0730
23	5.5	6	2	2	4	4	1.5	1.5	3.5	0.5	2.5	2.5
24	5	6	2.5	3	5.5	5.5	2	2	2.5	1.5	4	3
25	2	3.5	1.5	1	2.5	5	1	2	1.5	0.5	2	2
26	2.5	2.5	1	2	3.0	4	2	2	3	2	3	2

* Refer to Table XLV for component designation.

TABLE LII
MODELS T53-L-9A AND T53-L-11 ENGINES N_2 COMPONENT
CONDITION METER READINGS SUMMARY

	Condition Meter Readings										
	Engine Serial Number (LE Series) and Aircraft Serial Number										
	10822	06238	10822	11075	06092	03117	11303	06224	09645	12595	06514
Item*	62-1950	62-1928	62-1950	61-0760	62-1874	61-0724	62-1962	62-4604	61-0745	66-1038	61-0719
1	3.0	3.0	3.5	2.0	4	2.5	2.5	2.5	3	2.5	2
2	2.5	3.0	1.0	1.5	3	4.5	1.5	2.5	1.5	1	1.5
3	3.0	3.0	1.0	1.0	2.5	3	1.5	1.5	2.5	1.5	3
4	3.0	2.5	2.3	3.5	4.5	5	3.5	3.5	6	3	4
5	2.5	3.0	2.3	1.5	2.5	4	1.5	2	1.5	1	2.5
6	2.5	2.5	2.0	2.5	3	3.5	1.5	2.5	2	1	3
7	1.5	2.0	2.5	1.5	2	2.5	1.0	2.5	2	0.5	1.5
8	2.5	3.5	7	3.0	6.5	5.5	3	2.5	5	2	2.5
9	2.5	2.5	7	1.0	2.5	2.5	1.5	1	2	0.5	1.5
10	4.0	3.0	4.5	1.5	2.5	2	1	1.5	1.5	1.5	1
11	3.0	2.5	3.0	3.0	7	5	2.5	2	4	2.5	2.5
12	3.0	3.5	7.0	1.5	3.5	4.5	2	3	2.5	1	2
13	2.0	3.0	1.0	1.5	2	3.5	1	2	1.5	1	1.5
14	3.5	4.0	2.0	2.0	3.5	3.5	1.5	2.5	2	1.5	1.5
15	3.5	2.5	9.5	2.0	7.5	6	6	3.5	2.5	1	3
16	3.0	2.5	3.5	2.0	4.0	4	2.5	3	3	2.5	2.5

* Refer to Table XLVI for component designation.

TABLE LIII

TRANSMISSION COMPONENT CONDITION MI

Item	62-1950 UH-1B	62-1928 HU-1B	62-1950 UH-1B	63-12910 UH-1B	61-0760 UH-1B	59-1667 HU-1A	62-1874 UH-1B	61-0724 UH-1B	62-1962 UH-1B	62-4 UH-
1	2.5	2	5	2	6.5	1	2	2	3	1.
2	2	1.5	6.5	1	3	1	3.5	1	6.5	1.
3	4	2	9	2	3.5	1	2	1	8	1
4	3	3	P	4.5	7	5	3	2.5	4.5	2
5	3.5	2	P	4	3.5	2.5	3	1.5	4.5	1.
6	2.5	3	6.5	4	5	5.5	3.5	2	7.5	2
7	5	5.5	6	6	8	3	P	7	10	5
8	3	3.5	6.5	4	5	5	3.5	6	3.5	2
9	-	-	-	-	-	-	-	-	-	-
10	3.5	3	5.5	3	3.5	2	2.5	2.5	4.5	2.
11	4.5	4	7	2.5	10	2	3	3.5	6	3
12	-	-	-	-	-	2.5	-	-	-	-
13	-	-	-	-	-	3.5	-	-	-	-
14	-	-	-	-	-	3.5	-	-	-	-
15	-	-	-	-	-	2.5	-	-	-	-
16	-	-	-	-	-	4	-	-	-	-
17	-	-	-	-	-	3	-	-	-	-
18	-	-	-	-	-	4	-	-	-	-
19	-	-	-	-	-	2	-	-	-	-
20	3.5	6	5	4	4	-	4	4	6.5	2.
21	2.5	6.5	5.5	3	3.5	-	3	4.5	6.5	3.
22	4	6.5	8	3.5	5	-	5	4	6.5	3.
23	2	3.5	6	3.5	3.5	-	2.5	3	6	4

A

TABLE LIII

NENT CONDITION METER READINGS SUMMARY

0724 -1B	62-1962 UH-1B	62-4604 UH-1B	61-0745 HU-1B	66-1038 UH-1D	61-0719 UH-1B	59-1703 UH-1A	60-3537 UH-1A	59-1703 UH-1A	61-0730 UH-1B	63-8704 UH-1B
	3	1.5	3.5	3	1.5	2.5	2	0.5	7	1.5
	6.5	1.5	2	2	4.5	3.5	2.5	1	3	2
	8	1	2.5	2	2.5	3.5	7	1.5	8	4
.5	4.5	2	5.5	4	5	4	5.5	2.5	5	2.5
.5	4.5	1.5	1.5	4	1.5	3	3.5	2.5	4	1.5
	7.5	2	3	4.5	4	4.5	10	6	3.5	9
	10	5	5.5	3.5	5	3.5	3	1.5	4.5	9.5
	3.5	2	3	3	3.5	2.5	3.5	1.5	4.5	4.5
	-	-	-	4	-	-	-	-	-	-
.5	4.5	2.5	2	4	1.5	1	1.5	1	3	4
.5	6	3	5.5	5	2.5	3	2.5	1	P	2
	-	-	-	-	-	1.5	2	1.5	-	-
	-	-	-	-	-	2	3	1	-	-
	-	-	-	-	-	1.5	1.5	1	-	-
	-	-	-	-	-	1	3.5	1	-	-
	-	-	-	-	-	1.5	2	1	-	-
	-	-	-	-	-	1.5	1.5	1	-	-
	-	-	-	-	-	2	1.5	1	-	-
	-	-	-	-	-	1.5	3.5	1	-	-
	6.5	2.5	3	4.5	1	-	-	-	3	3.5
.5	6.5	3.5	3.5	4.5	1	-	-	-	4	3
	6.5	3.5	5	3	2	-	-	-	5	3
	6	4	1.5	4.5	2.5	-	-	-	2	4.5

B

TABLE LIV
GROUP I TRANSMISSION BEARING CONDITION

Item	62-1950 UH-1B	62-1928 HU-1B	62-1950 UH-1B	63-12910 UH-1B	61-0760 UH-1B	65-10032 UH-1D	59-1667 HU-1A	62-1874 UH-1B	61-0724 UH-1B	62-1962 UH-1B
1	-	-	-	-	-	1.5	-	-	0.5	0.7
2	-	-	-	-	-	1.5	-	-	0.2	0.2
3	-	-	-	-	-	1	-	-	0.2	0.1
4	-	-	-	-	-	1.5	-	-	1	3
5	-	-	-	-	-	1.5	-	-	1	1
6	-	-	-	-	-	1.5	-	-	0.8	0.6
7	-	-	-	-	-	1.0	-	-	0.5	0.7
8	3.5	4.5	6.5	5	0.5	-	1.5	2.5	5	7
9	2.5	3.5	4.5	5.5	5	-	3	5	2	5.5
10	4.5	5.5	6	1.5	3.5	-	2.5	2.5	1.5	2.5
11	2.5	2.5	3.5	1.5	3.5	-	4.5	2	1.5	3.5
12	6.5	4	8	6	9.5	-	5	6	3	8.5
13	6	3.5	5.5	3.5	5	-	3.5	2.5	2	8.5
14	5	3.5	8	2.5	5	-	3.5	2.5	3	7.5
15	4.5	3	4	2.5	3.5	-	3	2.5	2.5	6.5
16	2.5	8.5	2.5	3.5	2	-	3.5	1.5	2	6
17	3.5	4.5	3.5	5	5.5	-	6	3.5	4	P
18	3	6	2.5	3.5	3	-	3	1.5	2	6
19	2.5	3	6	6	3	-	6	2	3.5	P
20	1	1.5	1.5	2	2.5	-	1.5	1	1	3.5
21	3	2.5	5.5	2.5	3.5	-	3	2.5	2.5	4.5
22	4	2.5	3	3.5	2.5	-	3	2	6	6.5
23	P	P	P	8	6	-	6.5	8	6.5	10
24	2.5	2.5	3.5	2.5	2.5	-	1.5	1.5	1.5	2.5
25	2	2	2.5	2.5	3.5	-	2.5	2.5	3	4
26	3	2.5	3	5	4	-	4.5	2.5	3.5	7
27	3	2	5.5	4	3.5	-	5.5	2.5	4	9.5
28	5	2	4.5	5	7	-	6	3	3	7

TABLE LIV

EARING CONDITION METER READINGS SUMMARY

61-0724 UH-1B	62-1962 UH-1B	62-4604 UH-1B	61-0745 HU-1B	66-1038 UH-1D	61-0719 UH-1B	59-1703 UH-1A	60-3537 UH-1A	59-1703 UH-1A	61-0730 UH-1B	63-8704 UH-1B
0.5	0.7	0.5	1.5	2	1	2.5	1	2.5	1.5	1.5
0.2	0.2	0.2	1	1	0.5	1.5	1.5	1.5	1.5	1
0.2	0.1	0.2	1	1	0.5	1	0.5	1	2	1
1	3	3	2	3	5.5	2	1	2	1	2
1	1	0.8	1.5	2	1.5	1.5	2	1.5	0.5	1.5
0.8	0.6	0.5	1	2	1.5	2	1	2	1.5	1
0.5	0.7	0.4	1	2	0.5	1.5	1	1.5	1.5	1
5	7	4.5	3.5	4	2.5	1.5	2.5	4.5	3.5	4
2	5.5	3.5	4	1.5	4	1.5	2	2	2	4.5
1.5	2.5	3.5	1	1.5	1.5	2	2	1.5	1	2.5
1.5	3.5	3.5	3	2.5	1.5	1.5	3.5	2.5	1	1.5
3	8.5	9	2.5	2.5	3.5	-	3	3	2.5	4.5
2	8.5	6	5.5	5	2.5	-	4.5	4	3.5	3.5
3	7.5	5	4	4.5	1.5	-	4	4.5	2.5	2.5
2.5	6.5	3.5	3.5	4.5	1.5	-	4.5	2.5	2	2.5
2	6	5.5	5	2	3	-	2	1	1.5	1.5
4	P	6	6	6	3.5	-	5.5	6	4	4
2	6	3	5	4	2	-	5.5	4	2.5	2.5
3.5	P	4	3	8	5	-	5	3.5	2	3.5
1	3.5	2.5	2.5	2	1	-	3	1.5	1.5	2
2.5	4.5	3	3.5	4	1.5	-	3	2	1.5	3.5
6	6.5	7	4	7	6	-	3.5	3.5	3.5	4.5
6.5	10	5	2	5	P	-	9	5	6	P
1.5	2.5	3	1.5	2	2	-	2	1.5	1.5	1.5
3	4	3	3	4.5	3	-	4.5	3	1.5	2
3.5	7	3.5	5	6	2.5	-	7.5	3.5	3	2
4	9.5	3	3	5	4	-	4	3	2	P
3	7	5	4	5	5	-	5	4	3	4

TABLE LV

GROUP II TRANSMISSION BEARING CONDITION METE

Item	62-1950 UH-1B	62-1928 HU-1B	62-1950 UH-1B	63-12910 UH-1B	61-0760 UH-1B	59-1667 HU-1A	62-1874 UH-1B	61-0724 UH-1B	62-1962 UH-1B	62-4604 UH-1B
1	1	1	2	3.5	1.5	1.5	1	1	3.5	1.5
2	2	2	3.5	5.5	3.5	2	3	2.2	5	3
3	4	3.5	4	8.5	3	2	2	2.5	5.5	3
4	2.5	2	4	3	4	2	2	1	3	1.5
5	1	1.5	3	4.5	2.5	1	2	2	3	2
6	2.5	3	4	4.5	4.5	2.5	2.5	3.5	6.5	3.5
7	2.5	3	3.5	9	4.5	2	2	3	7	3
8	4	2.5	3.5	4	3.5	4.5	1	2	3	3
9	1.5	1.5	3.5	3.5	3.5	3	2	1.5	3.5	2.5
10	3.5	1.5	5.5	8	3	3	1.5	3	5	3.5
11	2.5	2.5	3.5	6.5	4	1.5	2	3	6	4
12	2.5	1.5	2.5	3.5	2.5	2.5	1.5	2.5	5	2.5
13	1.5	2	3.5	4	2.5	2	2.5	1.5	3.5	3
14	3.5	4	6	6.5	3	3	2	3	5	3
15	3	3	3	6.5	3.5	2.5	2	3	6	4
16	3	2.5	4	2.5	3	2	1	1	3.5	5
17	1.5	1	2.5	2.5	3	1.5	1	1	2.5	2
18	1.5	3	3.5	4	1.5	1	1	1	7	2.5
19	3.5	2.5	5.5	5.5	3	2	1.5	3.5	4.5	4
20	2	3	4	3	2.5	1.5	1.5	1.5	2.5	2.5
21	2.5	2.5	4.5	5.5	3	2	2	3	6	5
22	P	P	P	P	7	3	3.5	6	9.5	P
23	2.5	2	3	6	4	3	2	2	7	3.5
24	6	3	6	6.5	6	2.5	2	3	6	6
25	2	-	-	-	-	-	2	0.5	-	-
26	2	-	-	-	-	-	2.5	1.0	-	-
27	0.5	-	-	-	-	-	1.5	0.7	-	-
28	2.5	-	-	-	-	-	4.5	0.8	-	-
29	5	2.5	4	4.5	4.5	1	4	2	7	2.5
30	2	2	3	2	2.5	1.5	1.5	2	3.5	2
31	2	2.5	2.5	4	1.5	1.5	1	1.5	3	2.5
32	3	2	2.5	3.5	3.5	3.5	2	1.5	6	1.5
33	4	3.5	5	4.5	4	2	2	2	5	3
34	3.5	6	5.5	P	3	2.5	2.5	P	8	P
35	4	4	6	8.5	P	P	7.5	5.5	9	3
36	2	1.5	3	2	5	1.5	3.5	1.5	3	2

A

TABLE LV

EARING CONDITION METER READINGS SUMMARY

724 1B	62-1962 UH-1B	62-4604 UH-1B	61-0745 HU-1B	66-1038 UH-1D	61-0719 UH-1B	59-1703 UH-1A	60-3537 UH-1A	59-1703 UH-1A	61-0730 UH-1B	63-8704 UH-1B
	3.5	1.5	2.5	3.5	2	-	3	3	2	2
2	5	3	2.5	4.5	2	-	5	4.5	3	2.5
5	5.5	3	3.5	4.5	4.5	-	3.5	3.5	2	8.5
	3	1.5	2.5	2.5	2.5	-	2.5	2.5	3	3.5
	3	2	2.5	3	1.5	-	2	2.5	2.5	2
.5	6.5	3.5	3	5.5	3.5	-	5	5	3	4
	7	3	4	6	3.5	-	6.5	4.5	1.5	4
	3	3	2.5	2.5	2.5	-	2.5	2.5	1.5	3
.5	3.5	2.5	2.5	3	1.5	-	4.5	2	2	2
	5	3.5	3.5	5	2.5	-	3.5	4	1.5	2.5
	6	4	2.5	4	5.5	-	3	3	1.5	2
.5	5	2.5	2.5	2	2	-	2	1.5	1.5	2
.5	3.5	3	2.5	2.5	2	-	1.5	2	1.5	2.5
	5	3	3	5	2.5	-	2.5	2.5	2	3
	6	4	4	6.5	3	-	3	2.5	2.5	6.5
	3.5	5	1.5	2	2	-	2.5	1.5	2	3.5
	2.5	2	2	2.5	2	-	1.5	2	2	1.5
	7	2.5	1.5	2.5	4	-	3	2.5	2	4.5
.5	4.5	4	3	4	3	-	2	3	2	3
.5	2.5	2.5	2.5	2	1.5	-	1.5	1	1.5	1.5
	6	5	4	4	4	-	3	4.5	2	3.5
	9.5	P	4.5	5	P	-	7.5	4.5	6	P
	7	3.5	4.5	4	5	-	6	5	2	2
	6	6	5	4	4	-	6.5	5.5	1.5	2.5
.5	-	-	1.5	2.5	1	1.5	1	-	1.5	1.5
.0	-	-	2	2.5	3.5	4	1.5	-	1.5	1
.7	-	-	1.5	2.5	4	1	1.5	-	2.5	1
.8	-	-	1.5	4.5	1	1	1.5	4	2	1.5
	7	2.5	5	1.5	4.5	-	2.5	2	2.5	5
	3.5	2	2	1	1.5	-	1.5	2	1	1.5
.5	3	2.5	3	1.5	2	-	2.5	2.5	1	1.5
.5	6	1.5	3	3	2	-	2.5	2	1.5	4
	5	3	3	3	2	-	3.5	4	2	3.5
	8	P	4.5	8	P	-	5	4	3.5	P
.5	9	3	6	5	5.5	-	8.5	7	3	P
.5	3	2	1.5	1.5	2.5	-	7	2	0.5	2

B

TABLE LVI

TAIL ROTOR DRIVE COMPONENT CONDITION

Item	62-1950 UH-1B	62-1928 HU-1B	62-1950 UH-1B	63-12910 UH-1B	61-0760 UH-1B	65-10032 UH-1D	59-1667 HU-1A	62-1874 UH-1B	61-0724 UH-1B	62-1962 UH-1B
1	4.5	5.5	4.5	1	4.5	5.5	9.5	3.5	2.5	4
2	8.5	6.5	P	2.5	5	7.5	5	7.5	P	P
3	3.5	4	4.5	2	3.5	9	5	3.5	3	5
4	4.5	3.5	6	5	5.5	9	4.5	3	3.5	5
5	8	5	7.5	2	5	9	8.5	5.5	5.5	8
6	5.5	9	5	1.5	4.5	4.5	7.5	4	2.5	5
7	5	6	5.5	1.5	6	7	5.5	4	5	5
8	5.5	3	7.5	1.5	3	6	4.5	3.5	8	8
9	3.5	4.5	6	2	4	4.5	6.5	4	5.5	5.5
10	P	P	P	4	9	8	9.5	8.5	9.5	P
11	5	4	5	2	6	4.5	5	3.5	3.5	5
12	6.5	6	6.5	2	5	10	6.5	4	8	5.5
13	7.5	8	7	3.5	6.5	9.5	5	4	5	7
Noise	2.5	1.5	1.5	0.7	1	2.5	1	0.5	1.5	1
14	7.5	8	7	4.0	6.5	9.5	5	4	5	7
15	2	4	2	0.5	2.5	6.5	2.5	1	4	3
16	1.5	3.5	1.5	0.5	1.5	2.5	1.5	1.5	3.5	2.5
17	0.5	1	0.5	0	0.5	5.5	1.5	0.5	0.5	0.5
18	8.5	6.5	8.5	1.5	5.5	6.5	8	7	9.5	8.5
Noise	1.5	1.5	1.5	1.0	1	3.5	1.5	0.5	2	1
19	8.5	6.5	8.5	1.5	5.5	6.5	8	7	9.5	8.5
20	3.5	3	4	1.5	4	5.5	4.5	2.5	6	2.5
21	2	3	1.5	1.0	1.5	2	3	1.5	2.5	2
22	2	3	3.5	3	2.5	3	1.5	2	3.5	3.5

TABLE LVI

PONENT CONDITION METER READINGS SUMMARY

61-0724 UH-1B	62-1962 UH-1B	62-4604 UH-1B	61-0745 HU-1B	66-1038 UH-1D	61-0719 UH-1B	59-1703 UH-1A	60-3537 UH-1A	59-1703 UH-1A	61-0730 UH-1B	63-8704 UH-1B
2.5	4	7	2	4.5	4	3	3	2.5	5.5	1.5
P	P	10	4.5	6.5	8.5	5	10	6.5	7	2
3	5	7	3.5	8	4	4	4	2.5	4.5	1
3.5	5	9	1.5	6	3	3	3	2.5	4	2
5.5	8	10	3	9	5.5	6	6	5.5	7.5	2.5
2.5	5	8	3	5.5	4	4.5	3.5	2.5	4.5	1.5
5	5	7	4	9.5	5.5	3.5	5.5	5	5	4
8	8	6.5	1.5	7	4.5	9.5	4.5	4.5	3.5	2.5
5.5	5.5	6.5	3	6	3.5	3.5	3.5	3	4.5	2
9.5	P	8.5	5	7	P	5.5	9.5	7.5	7.5	3.5
3.5	5	6.5	3	4.5	3.5	2.5	3.5	3	5.5	2
8	5.5	9	3.5	7.5	5	6.5	4.5	4.5	4.5	3
5	7	9.5	6.5	6	8.5	8.5	3.5	5.5	5.5	6.5
1.5	1	3.5	1.0	2	1	3	1	1.5	1	1
5	7	9.5	6.5	6	9.0	8.5	3.5	4.5	5.5	6.5
4	3	6.5	1	2.5	2.5	2	1.5	2	1	1.5
3.5	2.5	2	1	3.5	3	1.5	2.5	1.5	1	1
0.5	0.5	0.5	1.5	6	3	0.5	1.5	1	1.5	0.5
9.5	8.5	5.5	5.5	8.5	4	4	7.5	6.5	6	6.5
2	1	1.5	0.5	2	1.5	1.5	1	0.5	1	0.5
9.5	8.5	5.5	5.5	8.5	3.5	3.5	7.5	6.5	7	6
6	2.5	4.5	2.0	2.5	2	2	3	1.5	1.5	2
2.5	2	4	1.5	3	2.5	2.5	2	2	1.5	1.5
3.5	3.5	2	1.5	7	1.5	2.5	2.5	1.5	2.5	0.5

15

TABLE LVII
COMPONENT GAIN SETTINGS FOR SELECTED COMPONENTS OF THE TAIL ROTOR DRIVE AND THE TRANSMISSION (REVISED GAINS)

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
	Start						
	Clear						Set RPM Meter
	N1 Cal		Cal	N1	.3321	5-5	Set Max
	N2 Cal		Cal	N2	.3533	5-5	Set Max
	Mic 1 Normalize						
	(Test Level - 10)		1	N1	1.1223	5-25	Set 5
	1st-Stage Compressor						
	(Lock Check)		1	N1	.7333	5-10	Peg
	Mic 3 Normalize						
	(Test Level - 10)		3	N1	1.1223	5-25	Set 5
1	Bearing (46) - Tail	f_1	3	N2	.0304	1-5	Reject 8
2	Drive Shaft Support	f_2*	3	N2	.0215	3-0	Reject 8
3		f_B'	3	N2	.0266	1-5	Reject 8
4		$3f_B'$	3	N2	.1043	2-15	Reject 8
5	Bearing - Quill	f_1	3	N2	.0376	5-10	Reject 8
6	Assembly-Single Row	f_2	3	N2	.0257	1-5	Reject 8
7	42° Gear Box (42)	f_B'	3	N2	.0241	1-5	Reject 8
8		$3f_B'$	3	N2	.0743	5-5	Reject 8
-	Mic 3 Normalize Check		3	N1	1.1223	5-25	Check 5
9	Bearing - Quill	f_1	3	N2	.0341	3-10	Reject 8
10	Assembly-Double Row	f_2*	3	N2	.0217	3-0	Reject 8
11	42° and 90° Gear						
	Boxes (43)	f_B'	3	N2	.0203	3-0	Reject 8
12		$3f_B'$	3	N2	.0611	5-10	Reject 8
13	Bevel Gears - 42° Gear						
	Box Fundamental		3	N2	.1474	4-0	Reject 8
-	Noise Check (Storage)		3	N2	.1553	4-0	Record
14	Bevel Gears - 42° Gear						
	Box Fundamental		3	N2	.1474	4-0	Record
15	(50,51)	$-f_R$	3	N2	.1436	4-0	Reject 1/2 of 14
16		$+f_R$	3	N2	.1533	4-0	Reject 1/2 of 14
17		X2	3	N2	.3171	4-0	Reject 1/2 of 14
-	Mic 3 Normalize Check		3	N1	1.1223	5-25	Check 5
18	Bevel Gears - 90° Gear						
	Box Fundamental		3	N2	.0714	2-0	Reject 8

TABLE LVII (CONT'D)

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
-	Noise Check (Storage)		3	N2	.0773	2-0	Record
19	Bevel Gears - 90° Gear Box Fundamental		3	N2	.0714	2-0	Record
20	(52, 53)	$-f_R$	3	N2	.0655	2-0	Reject 1/2 of 19
21		$+f_R$	3	N2	.0753	2-0	Reject 1/2 of 19
22		X2	3	N2	.1630	2-0	Reject 1/2 of 19
-	Mic 1 Normalize (Test Level - 10)		1	N1	1.1223	5-25	Set 5
23	Main Rotor Low Speed Gears (10, 11, 12) and Hydraulic Pump		1	N2	.0423	5-15	Reject 8
24	Main Rotor Low Speed Gears	X2	1	N2	.1046	5-15	Reject 8
25	Lower Transmission Output Drive Gears (15, 16, 17)		1	N2	.1435	3-15	Reject 8
26	Lower Transmission Output Drive Gears	X2	1	N2	.3072	3-15	Reject 8
27	Main Rotor High Speed Gears (7, 8, 9)		1	N2	.1520	5-15	Reject 8
28	Lower Transmission Offset Spur (13, 14)		1	N2	.2273	5-15	Reject 8
29	Input Drive Bevel Gears (1, 2, 3)		1	N2	.2525	5-5	Reject 8
30	Input Drive Bevel Gears	X2	1	N2	.5253	1-15	Reject 8
31	Oil Pump		1	N2	.0166	5-10	Reject 8
	Mic 1 Normalize Check		1	N1	1.1223	5-25	Check 5
32	Bearing-Swash Plate	f_1	1	N2	.0145	5-10	Reject 8
33	UH-1B/1C/1D (48)	f_2	1	N2	.0137	5-10	Reject 8
34		f_B'*	1	N2	.0107	5-5	Reject 8
35		$3f_B$'	1	N2	.0325	5-15	Reject 8
36	Bearing (37)-Main	f_1	1	N2	.0032	5-20	Reject 8
37	Rotor Shaft Upper	f_2	1	N2	.0024	5-20	Reject 8
38	Support	f_B'	1	N2	.0021	5-20	Reject 8
39		$3f_B$'	1	N2	.0062	5-20	Reject 8
	Mic 1 Normalize Check		1	N1	1.1223	5-25	Check 5

TABLE LVII (CONT'D)

Item No.	Component		Mic Select	Lock Select	Ratio Set	Gain Set	Condition Level
40	Bearing (39)-Main	f_1	1	N2	.0043	5-20	Reject 8
41	Rotor Shaft Lower	f_2	1	N2	.0035	5-20	Reject 8
42	Support	f_B'	1	N2	.0031	5-20	Reject 8
43		$3f_B'$*	1	N2	.0112	5-10	Reject 8
44	Bearing (23)-Input	f_1	1	N2	.1056	5-20	Reject 8
45	Quill Assembly -	f_2	1	N2	.0736	5-20	Reject 8
46	Single Row	f_B'	1	N2	.1133	5-20	Reject 8
47		$3f_B'$	1	N2	.3421	5-20	Reject 8
48	Bearing (43) - Tail						
	Rotor	f_1	1	N2	.0341	5-15	Reject 8
49	And Accessory	f_2	1	N2	.0217	5-15	Reject 8
50	Output Quill Assem-	f_B'	1	N2	.0203	5-15	Reject 8
51	bly-Double Row	$3f_B'$	1	N2	.0611	5-25	Reject 8
-	Mic 1 Normalize Check		1	N1	1.1223	5-25	Check 5
52	Bearing (36)-Main	f_1	1	N2	.0072	5-15	Reject 8
53	Rotor Low Speed	f_2	1	N2	.0065	5-15	Reject 8
54	Rotating Carrier	f_B'	1	N2	.0055	5-15	Reject 8
55	Support	$3f_B'$	1	N2	.0210	5-15	Reject 8
56	Bearing (41)-Lower	f_1	1	N2	.0365	3-15	Reject 8
57	Transmission	f_2	1	N2	.0251	3-15	Reject 8
58	Input Quill Assem-	f_B'	1	N2	.0234	3-15	Reject 8
59	bly-Single Row	$3f_B'$	1	N2	.0722	5-20	Reject 8

* Similar Frequency Components

BLANK PAGE

TABLE LVIII

CONDITION METER READINGS SUMMARY F

OF THE TAIL ROTOR DRIVE AND THE TRANSM

Item	0760	0724	1962	0745	0719	0730	8704	8548	1964	8548	1888	3562	0763	0370
1	2.5	5	5.5	2.5	5	4	2	1.5	3	1.5	4	4.5	1	3.5
2	4	4.5	6.5	2	8	5	2.5	1	6.5	1.5	2.5	5.5	5	5.5
3	2	3.5	4.5	2.5	3.5	5	1.5	1	2.5	1.5	3	5	2	7
4	4	5	5	2	3.5	3.5	3	2	4	1.5	3.5	5	2.5	P
5	3.5	6.5	6.5	2.5	4.5	6.5	3	2	5.5	3	5.5	7	2	P
6	2.5	4.5	5	2.5	3	4.5	1.5	1	3	1.5	4	5	1.5	5
7	5.5	4	5	3	6	5	2.5	1.5	8	1.5	P	9	4.5	P
8	2.5	6.5	6.5	1.5	5	3	2.5	5	4	5	4	4	4	9.5
9	7.5	5.5	7.5	3	4.5	8	3	1.5	2.5	2.5	7.5	9.5	2	7
10	6.5	6	7.5	1.5	7.5	6	2.5	2	5.5	2	5	4	2	5
11	5	3	5.5	2	4	5	1.5	1	3	3	3.5	4.5	1.5	3.5
12	6.5	9	7	3.5	4.5	5	3.5	4	4	4	6.5	6	1	6
13	8	4.5	8.5	1	8.5	5	7.0	4.5	8.5	4	7.5	9	1.5	8
Noise	1.5	1.5	1.5	0.5	0.5	0.5	0.5	1	1.5	0.5	1	1.5	0.5	1.5
14	8	4.5	8.5	1.5	8.5	4.5	7.0	4.5	8.5	5	7.5	9.5	1.5	8.5
15	3.5	3	3.5	1.5	3	1	1	2.5	1	2	3.5	4.5	0.5	3.5
16	2.5	3.5	3	1	3	0.5	0.5	1	2	1	2.5	7	0.5	4
17	1.5	1	1	0.5	3	1.5	0.5	0.5	0.5	1	1	1.5	1	2
18	5	10	9.5	3	2.5	6	6.5	5.5	8	3.5	3.5	9.5	8	P
Noise	1.5	2.5	2	0.5	1.5	1.5	0.5	1	1	1	2	1.5	0.5	3.5
19	5	10	9.5	3	4	6	6.5	6	9	4.5	4	9.5	8	P
20	4.5	4.5	2.5	2	2	2	2	1.5	2	1	2.5	2	1.5	5
21	3	5	4.5	1	2	1.5	1.5	0.5	2	0.5	1.5	1	3	3.5
22	2.5	1	4	2	2.5	2.5	0.5	2.5	2	3	1.5	1	3.5	2.5
23	P	2	2.5	2.5	4.5	P	2	2.5	6.5	4.5	4.5	4	4	4
24	3	1.5	6.5	1.5	6.5	3.5	2	2.5	7.5	4	3	2.5	7.5	1.5
25	4	1.5	10	3	3.5	P	5	1.5	P	8.5	P	6.5	P	0.5
26	5	2	2.5	3	6	3.5	2	1.5	5	1.5	4.5	5	5	2
27	5	2.5	3.5	6	2.5	3.5	2	3	3.5	4	3.5	5.5	2.5	1
28	3	2.5	10	1.5	4	4.5	2	1.5	3	1.5	2	5.5	P	1.5
29	9	7.5	P	1.5	6	7	5	4	P	6.5	3.5	7	P	1.5
30	2.5	2	1.5	2	3	1.5	3	1.5	8	1.5	2	3	2	0.5
31	5	4	6	3.5	5	6	2.5	3	5	3	3.5	3	4	2
32	5	5	4	2.5	6.5	6.5	5	2	2	3	5	4	5	3.5
33	5	4	5	3	5	7	3.5	3.5	4.5	3	4.5	5	5	4
34	4.5	3	4.5	3.5	6	5	4	3.5	4.5	3.5	4	4	4.5	4
35	4	3	5.5	3	3.5	2	6.5	3	6	4	4	4	3	2.5

A

TABLE LVIII
GS SUMMARY FOR SELECTED COMPONENTS
THE TRANSMISSION FOR UH-1B HELICOPTERS

32	0763	0370	1964	0745	0724	1954	3562	0730	1964	0745	1964	3562	3547	0741	0724
5	1	3.5	2	2.5	4	2	3	3	2	1	1.5	2	0.5	2.0	1.5
5	5	5.5	4	3	8	3	4.5	5	2.5	1.5	2.5	1.5	1.5	2.0	1.5
	2	7	3.5	2	2.5	2.5	4.5	5.5	1.5	1.5	1	1.5	1	2.0	1
	2.5	P	2.5	3.5	6.5	2	3.5	8	1	0.5	1.5	1	0.5	1.5	1
	2	P	4	4.5	8	4	7.5	7.5	2.5	1	2.5	2.5	1	2	1.5
	1.5	5	2.5	3	5.5	2.5	4	3.5	1.5	0.5	1.5	2.5	1.5	1.5	0.5
	4.5	P	2	3	3.5	3	7	7.5	2	2	2	3	1.5	2.0	2
	4	9.5	3	6	7.5	2.5	9.5	9	1.5	1	1.5	1.5	1	1.5	3
5	2	7	4.5	3	4	3.5	4	6.5	3.5	2.5	2	2	1.5	1.5	2.5
	2	5	4	2.5	7	3	3.5	3.5	2.5	1	2.5	1.5	1.5	1.5	2
5	1.5	3.5	1.5	2	2.5	3	2.5	4.5	2	1.5	2	2	1	1.5	2
	1	6	4.5	2.5	8	3.5	5	7	2.5	1.5	3	1.5	1.5	1.0	3
	1.5	8	9.5	5	6	2	6.5	9	4.5	0.5	5	1.5	2	1.5	3
5	0.5	1.5	1	0.5	1.5	0.5	1	2	0.5	0.5	0.5	0	0	0.5	0.5
5	1.5	8.5	9	5	6.5	2	6.5	9	4.5	0.5	5.5	1.5	2	1.5	3
5	0.5	3.5	1	3.5	3.5	3.5	2.5	2.5	1	1	1	1.5	1	1	1.5
	0.5	4	1.5	1	3	1	1	2.5	1	0.5	1	1	0.5	0.5	0.5
5	1	2	1	0.5	1.5	1	1	2.5	0.5	0	1.5	0.5	0.5	0.5	1.5
5	8	P	6	4	10	5	6.5	4	1	1.5	4.5	2	0.5	1.5	8.5
5	0.5	3.5	1.5	2	3.5	0.5	1.5	1.5	0.5	0.5	0.5	0.5	0	0.5	1
5	8	P	6.5	4.5	10	5	6.5	4	2	1.5	6	1	1	1.5	8.5
	1.5	5	1.5	2.5	4.5	1.5	2	3.5	0.5	2	0.5	0.5	0.5	0.5	3
	3	3.5	2.5	3	3.5	2	3	3	1	0.5	0.5	0.5	1.5	0.5	2.5
	3.5	2.5	0.5	1.5	7	2	1	2	1.5	0.5	1.5	0.5	0.5	0.5	1.5
	4	4	P	6.5	4	1.5	4	P	4.5	2	8.5	2.5	5.0	2.5	4.5
5	7.5	1.5	4	2.5	2.5	2	2	4	3.5	1.5	6.5	2	3.5	4.5	2
5	P	0.5	P	6.5	7	2	3.5	2	7	0.5	P	1.5	7-P	P	6
	5	2	P	6.5	3	1	2	6	4	2	4.5	4	5.0	P	3.5
5	2.5	1	6	7.5	4	1.5	P	6	P	1.5	4.5	2	5	2.5	5.5
5	P	1.5	5	2.5	6.5	7.5	5.5	3	2	1	7	1	8-9.5	4	4
	P	1.5	8.5	9.5	10	1.5	8.5	P	P	0.5	P	8	7-9.5	P	P
	2	0.5	4.5	3	7	1	2.5	2.5	2.5	2	4	1	4.5	2.5	2.5
	4	2	3.5	2	6.5	3	2.5	3	3.5	3.5	4.5	2.5	7.5	4.5	4
	5	3.5	2	1.5	3	3	4.5	4	4.5	4	3	2.5	4.5	2.5	3.5
	5	4	3	2.5	6.5	3.5	6.5	4.5	3	2.5	4	3.0	6.0	6	4.5
	4.5	4	3.5	4	3	5	5	4.5	6.5	3.5	4.5	3.5	5.5	5.5	3
	3	2.5	1.5	2.5	4	2.5	5	3	3.5	2	4.5	3.5	4.5	4.5	3

B

TABLE LVIII (C

Item	0760	0724	1962	0745	0719	0730	8704	8548	1964	8548	1888	3562	0763	037
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	6.5	5.5	5-10	6	8-P	5	6.5	6	6	6.5	6.5	6.5	8.5	5
44	6.5	3.5	9	5	5	2.5	8.5	4.5	7	9.5	3	3	5	2
45	4	2	3	2	4	1.5	4	2	5	1.5	P	7	7	1.5
46	2.5	3	3.5	2	4	1	3	1.5	4.5	3	3.5	2	3.5	6
47	9.5	4.5	5	2	6	2	8	3.5	8.5	2.5	3.5	5	4	1.5
48	4	4	5.5	3	3.5	3	4.0	3	5	3	4	4	3.5	3.5
49	5	4.5	5	4	5	3-9	4.5	3	6	4.5	6.5	3	6.5	3
50	6	3.5	8-10	3	P	5-9	P	5	5.5	5	4.5	4	4.5	5
51	7	6	5-9.5	2.5	7.5	3.5	P	3	6	5	6.5	4	6.5	4
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	5	2	3.5	4	4.5	7-10	6	2.5	4.5	3.5	2	2	2.5	5
56	3.5	2	2.5	2.5	2.5	4	4	1.5	3	2.5	2	2	2.5	2
57	3	P	5.5	3.5	4	4.5	P	3	5.5	4	4.5	3	3	2.5
58	P	6.5	8-10	5	P	7.5	5	4.5	6.5	5	P	P	9.5	4.5
59	9.5	2	4	2	7	3	4	5	6	6.5	6.5	4.5	5	3

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ABLE LVIII (CONT'D)

2	0763	0370	1964	0745	0724	1954	3562	0730	1964	0745	1964	3562	3547	0741	0724
	-	-	2	3.5	2	3.5	5	5.5	-	7	5	-	6	3.5	3
	-	-	1.5	1.5	0.5	3	4	5.5	-	7.5	3-8	-	5.5	3.5	3
	-	-	1	1	1	3	2.5	1.5	-	7	2.5	-	5.5	3	4
	-	-	4.5	P	6	6.5	P	2	-	6	7-9	-	7.5	P	3.5
	-	-	2	6	6	4	8.5	2.5	-	7	6	-	7-P	3	2.5
	-	-	2.5	7	3	5	5	1.5	-	7	4.5	-	6	3	2
	-	-	2.5	3	2	3	4.5	1.5	-	9.5	3	-	3.5	4	2
5	8.5	5	4	4	5.5	6	7	6	7	4.5	6	4	7-9.5	3.5	3.5
	5	2	3	5	3	6.5	3.5	2.5	3.5	1.5	4.5	2	2.5	4	2
	7	1.5	3	1.5	3	4	7.5	1	2	4	4	1	5.5	2.5	4
	3.5	6	2	1.5	3.5	2	2	2	3	1.5	3	1.5	6-9	6.5	2
	4	1.5	[illegible]	5	4.5	7	5	4	4	3.5	9	4	5	6.5	2
	3.5	3.5	3.5	3	2.5	2.5	3.5	3.5	3	1.5	3	2	4.5	4	2.5
	6.5	3	1	4	4	3	5	4.5	6	5.5	9.5	2.5	4.5	5	2
	4.5	5	1.5	2	5	4.5	5	3.5	5.5	3	4.5	3	8-P	5	1.5
	6.5	4	2	4.5	2	2.5	4	2.5	4	2	8	3	6.5	6.5	2.5
	-	-	4.5	4.5	2	3	7	2.5	-	4	3	-	-	4.5	2
	-	-	2.5	6.5	3	3.5	5	1.5	-	3.5	2.5	-	-	3.5	2.5
	-	-	4	6.5	1.5	4	P	3	-	4.5	3.5	-	-	P	2.5
	2.5	5	1	1.5	4	0.5	4	3	2.5	3	3.5	2	3.5	3.5	1.5
	2.5	2	1.5	2	2.5	1.5	3	2	2.5	1	3.5	2	3	2.5	2
	3	2.5	1.5	3.5	P	2	3	2	3.5	2	4	2	5.5	3.5	1.5
	9.5	4.5	5	4	2.5	1	3.5	2	5	2.5	P	2.5	6-9	5	3.5
5	5	3	2.5	1.5	3	2	2.5	1.5	4	2.5	8	1.5	5.5	2.5	3.5

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TABLE L

TEARDOWN ANALYSIS OF CO
FROM UH-1B HELICOPTERS AT F

(All Inspection Results Based o

Component	Analyzer Indication - Bearings	Inspection Results
42° Gear Box S/N B13-4313 Removed from UH-1B S/N 61-0745 TT 832 hrs TSO 0 hrs TBO 1500 hrs	Below reject level.	No defects.
42° Gear Box S/N B13-2556 Removed from UH-1B S/N 61-0730 TT 89 hrs TSO 0 hrs TBO 1500 hrs	Double row bearings - below reject level. Single row bearings - 1 check above reject level on f_1, f_B' and $3f_B'$. Other 2 checks below reject level except 1 reading on $3f_B'$.	No defects.
90° Gear Box S/N A13-208 Removed from UH-1B S/N 61-0724 TT 346 hrs TSO 0 hrs TBO 1100 hrs	Double row bearing - below reject level except 1 reading on $3f_B'$. Single row bearing - not checked. NOTE: Double row bearing also used on 42° gear box and operates at same speed. This gear box not disassembled for inspection.	No defects.
90° Gear Box S/N B13-4108 Removed from UH-1B S/N 61-0745 TT 832 hrs TSO 0 hrs TBO 1100 hrs	Double row bearing - below reject level. Single row bearing - not checked.	No defects.
90° Gear Box S/N A13-206 Removed from UH-1B S/N 61-0730 TT 89 hrs TSO 0 hrs TBO 1100 hrs	Below reject level.	No defects.

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TABLE LIX

SIS OF COMPONENTS REMOVED
TERS AT FORT RUCKER, ALABAMA

ults Based on Visual Examination)

ion Results - Bearings	Analyzer Indication - Gears	Inspection Results - Gears
cts.	Fundamental low, sidebands low (absolute) but high relative to fundamental.	Wear pattern within ARADMAC's quality standards.
ects.	Fundamental above reject level on 2 of 3 checks. Sidebands and 2nd harmonic low (absolute) and low relative to fundamental.	Wear pattern within ARADMAC's quality standards.
ects.	Fundamental above reject level on 3 checks. 1 of 3 checks showed relatively high 2nd harmonic.	Loss of metal from load side of driven gear teeth. Driven gear considered to be reject and not repairable. Drive gear considered acceptable for re-use after rework to dress teeth.
fects.	Fundamental low. Sidebands low (absolute) but high relative to fundamental. 2nd harmonic high on 1 check.	Both gears show high wear and are considered to be reject. Drive gear definite reject due to pits on 2 teeth (load side) and not repairable. Driven gear may be accepted thru M.R. action, if acceptable gear wear pattern is obtained with new drive gear.
fects.	Fundamental above reject level on 1 check. Separate check showed relatively high sidebands. These indicators were marginal and unit was selected for inspection to establish if gains were close to proper levels.	Wear pattern just within acceptable limits; however, for relatively short operating time, pattern considered marginal. Would be corrected on next build-up (i.e., not acceptable for new or newly overhauled unit).

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Component	Analyzer Indication - Bearings	Inspection Results - Be
Transmission S/N A12-618 Removed from UH-1B S/N 61-0745 TT 1511 hrs TSO 411 hrs (1 overhaul) TBO 1100 hrs	Bearing 37 ($3f_B'$ - 1 recording) and bearing 39 (f_B' - 1 recording) above reject level. All other bearings on program tape below reject level.	Bearing 24 (triple row drive quill) showed 2 b wear and pitting on out Outboard bearing show of outer race turning in Bearing 28 (generator showed balls pitted and on inboard bearing. C reject. Bearings 37 an appeared satisfactory (available). NOTE: Bearings 24 an program tape.
Transmission S/N A12-801 Removed from UH-1B S/N 61-0730 TT 2060 hrs TSO 975 hrs (1 overhaul) TBO 1100 hrs	Bearing 43 (f_2 and f_B' - 1 check) and bearing 36 ($3f_B'$ - 1 check) showed fluctuating signals from normal to above reject level.	All bearings appeared
Transmission S/N B12-613 Removed from UH-1B S/N 62-1964 TT 806 hrs TSO 0 hrs TBO 1100 hrs	Bearing 37 (f_2 and $3f_B'$) showed fluctuating signals from normal to high on 1 check. Bearing 23 ($3f_B'$) showed high signal on 2 checks. Bearing 43 (f_2 and $3f_B'$) showed high signal on 1 check. Bearing 41 (f_B' and $3f_B'$) showed high signal on 1 check.	Bearing 42 (tail rotor shaft) showed rough sp race. All other bearin satisfactory. NOTE: Bearing 42 not tape.

NOTE: Underlined items were primary suspects in selecting the assembly for teardown inspection.

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ABLE LIX (CONT'D)

pection Results - Bearings	Analyzer Indication - Gears	Inspection Results - Gears
ring 24 (triple row - input ve quill) showed 2 balls with r and pitting on outer race. board bearing showed evidence outer race turning in housing. ring 28 (generator quill) wed balls pitted and scratched Inboard bearing. Considered a ect. Bearings 37 and 39 eared satisfactory (mast not ilable). TE: Bearings 24 and 28 not on gram tape.	Lower output bevel gears - fundamental low, 2nd harmonic relatively high on 3 checks. Low speed rotor gears - fundamental low, 2nd harmonic relatively high on 2 of 3 checks. Main input bevel gears - fundamental high on 1 of 3 checks.	All gears appeared to be satisfactory.
bearings appeared satisfactory.	Upper planetary gear train - high fundamental on 2 of 3 checks. Lower output bevel gears - high fundamental on 1 check and relatively high 2nd harmonic on 2 of 3 checks. Main input bevel gears - high fundamental on 1 of 3 checks.	Upper planetary gear train - chip on 1 tooth of sun gear - heavy wear pattern - considered reject. All other gears satisfactory. NOTE: Plastic plug in lower output bevel gear may have restricted oil flow thereby responsible for high signal observed. Gear wear pattern considered satisfactory.
ring 42 (tail rotor drive quill ft) showed rough spot on outer e. All other bearings appeared sfactory. TE: Bearing 42 not on program .	Lower output bevel gears - high fundamental on 3 of 4 checks and relatively high 2nd harmonic on 2 checks. Low speed rotor gears - high fundamental on 2 of 4 checks and relatively high 2nd harmonic on 3 checks. High speed rotor gears - high fundamental on 1 of 4 checks. Main input bevel gears - high fundamental on 4 checks.	All gears appeared satisfactory except evidence of metal passing thru high speed rotor gears as indicated by small pit on all planet gears and on sun gear (not considered a reject).

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APPENDIX

SAMPLE CALCULATIONS

The following sample calculations are based on data from models T53-L-9, T53-L-9A and T53-L-11 engines:

1. Compressor

Example: 1st stage = 26 blades, N_1 = 15088 RPM

(a) Fundamental rotational frequency

$$f_R = \frac{\text{Speed of compressor rotor, N1 (RPM)}}{60} = \frac{15088}{60} = 251.5 \text{ cps}$$

(b) Compressor rotor blade passage frequency

$$C_1 = f_R \times \text{no. of rotor blades} = 251.5 \times 26 = 6539 \text{ cps}$$

2. Accessory Drive Gear Box - Gas Producer Driven

Example:* Inner Drive Spur Gear (4b), N1 = 15088 RPM, gear (1) = 34 teeth, gear (2) = 63 teeth, gear (3) = 21 teeth, gear (4a) = 40 teeth and gear (4b) = 24 teeth.

* Refer to Figure 3 for location of these gears.

(a) RPM of gear

$$N_{gear(4b)} = N1 \times \frac{\text{No. of teeth on drive gear (1)}}{\text{No. of teeth on driven gear (2)}} \times \frac{\text{No. of teeth on drive gear (3)}}{\text{No. of teeth on driven gear (4a)}}$$

$$= 15088 \times \frac{34}{63} \times \frac{21}{40} = 4274.9 \text{ RPM}$$

(b) Rotational frequency

$$f_{gear(4b)} = \frac{\text{RPM of gear}}{60} \times \text{no. of gear teeth} = \frac{4274.9}{60} \times 24$$

$$= 1710 \text{ cps}$$

3. Bearing Formulae

Example: No. 1 Main Engine Bearing, N1 = 15088 RPM, d_B = 0.5000", d_1 = 2.2720", d_2 = 3.2720" and m = 13

(a) Fundamental rotational frequency

$$f_R = \frac{\text{RPM of shaft}}{60} = \frac{15088}{60} = 251.5 \text{ cps}$$

(b) Frequency caused by irregularity on inner race

$$f_1 = f_R \, m \, \frac{d_2}{d_1 + d_2}$$

$$= 251.5 \times 13 \times \frac{3.2720}{2.2720 + 3.2720} = 1929.6 \text{ cps}$$

(c) Frequency caused by irregularity on outer race

$$f_2 = f_R \, m \, \frac{d_1}{d_1 + d_2}$$

$$= 251.5 \times 13 \times \frac{2.2720}{2.2720 + 3.2720} = 1339.9 \text{ cps}$$

(d) Frequency caused by spin of rolling element

$$f_B = f_R \, \frac{d_2}{d_B} \, \frac{d_1}{d_1 + d_2}$$

$$= 251.5 \times \frac{3.2720}{0.5000} \times \frac{2.2720}{2.2720 + 3.2720} = 674.5 \text{ cps}$$

(e) Frequency caused by rough spot on rolling element

$$f_B' = 2 \, f_B = 2 \times 674.5 = 1349.0 \text{ cps}$$

(f) Frequency due to rotation of train of rolling elements

$$f_T = \frac{f_2}{m} = \frac{1339.9}{13} = 103.1 \text{ cps}$$

4. Octal Ratios

Example: Component frequency = 7504 cps
Tracking frequency = 6525 cps

(a) Decimal ratio

$$\text{Decimal ratio} = \frac{\text{component frequency}}{\text{tracking frequency}} = \frac{7504}{6525} = 1.15003$$

(b) Octal Ratio

Convert the decimal ratio to an octal ratio as follows:

(1) The number to the left of the decimal ratio is the first number of the octal number.

(2) Multiply all digits to the right of the decimal point in the decimal ratio by 8. The number to the left of the decimal point in this product is the first number to the right of the decimal point in the octal number.

(3) Multiply all digits to the right of the decimal point in the product obtained in (2) by 8. The number to the left of the decimal point in this product is the second number to the right of the decimal point in the octal number.

(4) Continue this process until the desired number of decimal places for the octal ratio is obtained.

(5) Round off last decimal place using the number 4 as the mid-point since these numbers are to base 8.

Example: Decimal ratio = 1.15003

Multiply
$$\begin{aligned} 0.15003 \times 8 &= 1.20024 \\ 0.20024 \times 8 &= 1.60192 \\ 0.60192 \times 8 &= 4.81536 \\ 0.81536 \times 8 &= 6.52288 \\ 0.52288 \times 8 &= 4.18304 \end{aligned}$$

Therefore, Octal Ratio = 1.1146 rounded off to 4 decimal places. If octal number had been 1.11475, the number rounded off to 4 decimal places would be 1.1150.

The use of an octal ratio rather than a decimal ratio in selecting the components to be analyzed is explained below.

The original breadboard design of the frequency ratio generator contained 13 mixer-divider cards to provide the ratio selected by utilizing a series of 13 on-off switches. It is common practice to show such an operation by a 13-digit binary number. However, the use of 13 switches in the analyzer would be rather cumbersome, and consequently, the 13-digit binary number was converted into a 5-digit octal number which results in much simpler wiring and switching than converting a binary number to a decimal number.

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13. ABSTRACT

The purpose of the work encompassed in this report was (1) to fabricate a CWEA-4 Diagnostic Sonic Analyser and (2) to design and fabricate a UH-1 helicopter plug-in module with both T53 engine and UH-1 helicopter power train components capability.

The methods employed in achieving this work consisted of (1) analysing mechanical data to determine the frequencies of the rotating components, (2) performing a microphone survey and locking frequency investigation, (3) analysing the acoustical data to develop spectral familiarity and to establish initial analyser programming and system compatibility, and (4) conducting a field application program utilizing the CWEA-4 Sonic Analyser to correlate analyser indications with the mechanical condition of the rotating components and to establish analyser limits.

As a result of the work accomplished under this program, a Curtiss model CWEA-4 Sonic Analyser, developed under Naval Air Systems Command Contract NOw 66-0706f, was fabricated and delivered to the Army. The UH-1 acoustic plug-in module, delivered with the analyser, was designed and fabricated under this program to incorporate the T53 engine (models T53-L-1A, T53-L-9, T53-L-9A and T53-L-11) and UH-1 helicopter power train components (transmission and tail rotor gear boxes) capability. The component limits were established during the three-month field application program conducted at the U.S. Army Aviation Center, Fort Rucker, Alabama.

A training program was conducted both at the U.S. Army Aviation Center, Fort Rucker, Alabama, and at the U.S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, to instruct personnel in the operation and maintenance of the CWEA-4 Sonic Analyser as well as in the diagnostic sonic analysis concept.

The utilization of the CWEA-4 Sonic Analyser by ground maintenance personnel at a military installation, such as Fort Rucker, Alabama, will reduce the aircraft downtime by eliminating unnecessary troubleshooting as now being practiced under conventional inspection methods. As the confidence level in the CWEA-4 analyser is increased, the time between periodic inspections may also be increased.

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Sonic Analysis - Gears						
Sonic Analysis - Bearings						
Sonic Analysis - Component Malfunctions						
Sonic Analysis - T53 Turbojet Engine						
Sonic Analysis - UH-1 Helicopter						
CWEA-4 Sonic Analyzer						

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